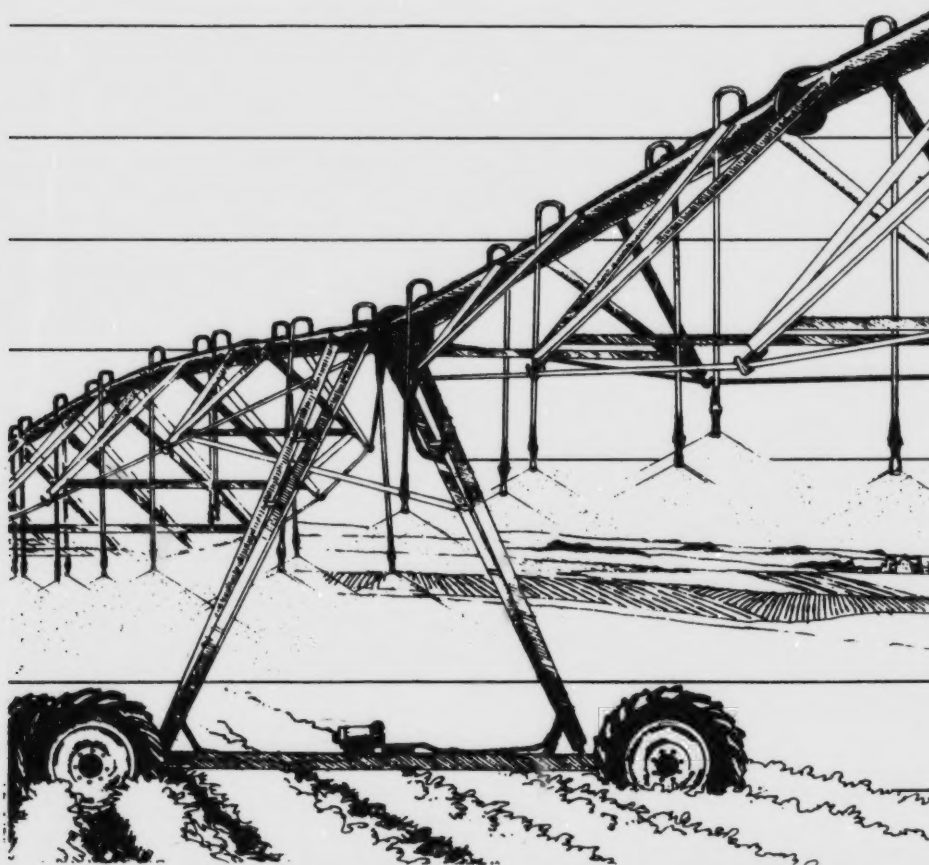




**Fourth Annual
Western Provincial Conference
Rationalization of Water
and Soil Research and Management**

**"IRRIGATION ON THE
PRAIRIES"**



Hosted by the Province of Saskatchewan
Saskatoon, Saskatchewan
November 25 to November 27, 1985

PROCEEDINGS
OF
FOURTH ANNUAL
WESTERN PROVINCIAL CONFERENCE
RATIONALIZATION OF WATER
AND SOIL RESEARCH AND MANAGEMENT

"IRRIGATION ON THE PRAIRIES"

HELD AT THE
CENTENNIAL AUDITORIUM, SASKATOON, SASKATCHEWAN
NOVEMBER 25 TO NOVEMBER 27, 1985

ORGANIZING COMMITTEE

J. F. DANYLUK
B. H. IRELAND
H. A. FJELD
R. D. CARNDUFF

SPONSORED BY THE GOVERNMENT OF SASKATCHEWAN
PROCEEDINGS PUBLISHED BY THE
SASKATCHEWAN WATER CORPORATION
MARCH 1986

COPIES OF THESE PROCEEDINGS MAY BE PURCHASED
AT \$15.00/COPY

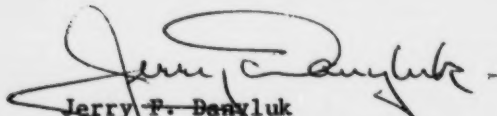
INTRODUCTION TO PROCEEDINGS

The Western Premiers' 1981 Conference supported an initiative to give priority attention to the rationalization of information, activities and research related to agricultural soil and water management. The idea was perhaps very simple but extremely important. To avoid large expenditures and lost time due to duplicating efforts in each of the provinces, experts and people in the industry would be brought together to share information and ideas on topics related to soil and water.

Saskatchewan was extremely pleased to have the opportunity to host the fourth annual western provincial conference on the topic of "Irrigation on the Prairies". The conference which was held in Saskatoon on November 25-27, 1985 was very well attended with delegates from as far away as Quebec.

The organizing committee has asked me to thank the speakers for their efforts in preparation and presentation of excellent papers. Contributions from speakers with various professional backgrounds from Canada and United States provided excellent food for thought and stimulated considerable discussion and questions. We are pleased to provide these proceedings containing the unedited versions of all formal presentations made at the conference.

My sincere thanks to members of the organizing committee - Rick Carnduff, Harvey Fjeld, Les Bohrsen and Bryan Ireland for co-ordinating the program and arranging the various functions and activities. But most importantly, I wish to thank all the delegates for their attendance and active participation.


Jerry F. Danyluk
Conference Chairman

IRRIGATION ON THE PRAIRIES

PROCEEDINGS

TABLE OF CONTENTS

	Page
Banquet Presentation from Government of Saskatchewan	1
Harold Martens, MLA Morse Constituency	
Address:	
Ron Larsen	27
Editor, Irrigation Age Magazine	
Address:	
V. C. Prudek	36
SESSION I: The Soil and Water Resource	
Irrigation on the Prairies - 1985	42
H. A. Fjeld	
Irrigation Branch	
Saskatchewan Agriculture	
Outlook, Saskatchewan	
Irrigation Water Quality - Soil Compatibility	50
Guidelines for Saskatchewan	
Dr. D. R. Cameron	
NORMAC A.E.S. Ltd.	
Swift Current, Saskatchewan	
Problem Water Utilization in Relation to Soil Salinity	64
J. L. Henry	
Department of Soil Science	
University of Saskatchewan	
Saskatoon, Saskatchewan	

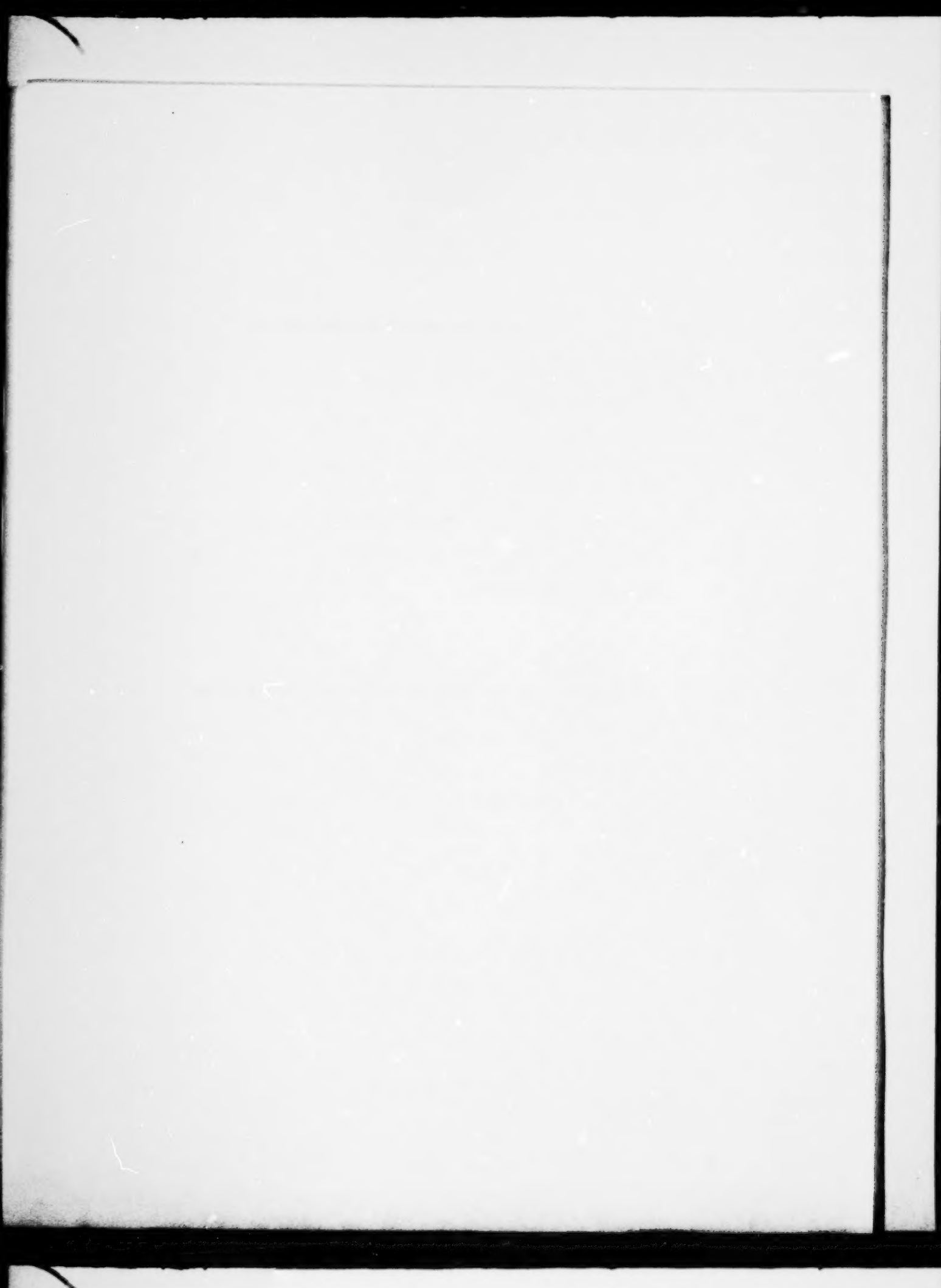
	Page
Irrigation Suitability Classification System for the Prairies R. G. Eilers Canada - Manitoba Soil Survey University of Manitoba Winnipeg, Manitoba	72
Application of Soils Information to Irrigation Planning and Management L. A. Leskiw Pedology Consultants Alberta	84
Effluent Irrigation on the Canadian Prairies Dr. F. F. Penkava Department of Agricultural Engineering University of Manitoba Winnipeg, Manitoba	103
SESSION II	
Maximizing Economic Crop Yields	
The Computer: Aid to Maximum Economic Yield P. O. Kresge AgriBasics Company Belgrade, Montana	108
Some Aspects of Climate as a Variable Affecting Irrigation Dr. C. F. Shaykewich Department of Soil Science University of Manitoba Winnipeg, Manitoba	119
and Dr. B. Grace Agriculture of Canada Research Station Lethbridge, Alberta	
and H. W. Cutforth Agriculture Canada Research Station Swift Current, Saskatchewan	
and D. M. Marantz Albert Soil and Feed Testing Laboratory Edmonton, Alberta	

	Page
Factors Affecting On Farm Irrigation Efficiencies	155
R. D. Monaghan, and A. E. Pungor Irrigation Branch Alberta Agriculture Lethbridge, Alberta	
Optimizing Wheat	165
Dr. B. D. Brown Department of Plant Soil and Entomological Sciences University of Idaho Parma, Idaho	
Optimizing Commercial Vegetables	172
Dr. M. K. Pritchard Department of Plant Sciences University of Manitoba Winnipeg, Manitoba	
Fertility Management to Optimize Canola Yields	179
J. T. Harapiak Western Co-operative Fertilizers Ltd. Calgary, Alberta	
Optimizing Alfalfa Production	193
Dr. L. D. Bailey Agriculture Canada Research Station Brandon, Manitoba	
 SESSION III: Developing Irrigated Agriculture	
The Economics of Water Use and Development in Agriculture on the Prairies	212
Dr. T. S. Veeman Department of Rural Economy University of Alberta Edmonton, Alberta	
Garrison Diversion, The Process	225
H. M. Olson Carrington Irrigation Station North Dakota State University	
Irrigation - The Option for Economic Development	233
D. H. M. Hill Prairie Farm Rehabilitation Administration Agriculture Canada Regina, Saskatchewan	

	Page
The Pearse Inquiry and Prairie Irrigation Dr. F. J. Quinn Inland Waters Directorate Environment Canada Ottawa, Ontario	246
Feasibility of Non-Intensive Irrigation J. L. Linsley Irrigation Branch Saskatchewan Agriculture Outlook, Saskatchewan	258
Feasibility of Supplemental Irrigation T. W. Hamlin Irrigation Branch Saskatchewan Agriculture Outlook, Saskatchewan	276
Irrigation, The Major Project Appraisal Dr. B. C. Palmer, and K. O'Grady UMA Engineering Ltd. Lethbridge, Alberta	284
Irrigation, The Individual Project Appraisal G. P. Gross and L. J. Bohrsen Irrigation Branch Saskatchewan Agriculture Outlook, Saskatchewan	313
The Economic and Financial Feasibility of Irrigation R. Desjardins, and J. Egglestone Economics Branch Alberta Agriculture	326

	Page
SESSION IV: Conference Summary and Recommendations	
Industry Wrap-up	351
H. G. Koch	
Irrigation Association	
Research Needs	357
Dr. J. D. Beaton	
Potash and Phosphate Institute	
Cochrane, Alberta	
Irrigation and Water Policy Implementation	365
D. J. A. Brown	
Department of Agricultural Economics	
University of Saskatchewan	
Saskatoon, Saskatchewan	

IRRIGATION ON THE PRAIRIES CONFERENCE REGISTRATION



BANQUET ADDRESS

HAROLD MARTENS, MLA MORSE CONSTITUENCY

GOOD EVENING. THANK YOU FOR INVITING ME TO SPEAK TO YOU AT YOUR FOURTH WESTERN PROVINCIAL CONFERENCE.

I'D LIKE TO WELCOME BACK THOSE OF YOU FROM OUTSIDE THE PROVINCE WHO WERE HERE TWO YEARS AGO WHEN SASKATCHEWAN HOSTED THE CONFERENCE ON SOIL EROSION AND LAND DEGRADATION.

TO THOSE OF YOU VISITING THE PROVINCE FOR THE FIRST TIME, I KNOW YOU WILL ENJOY YOUR STAY AND WILL GAIN USEFUL INSIGHT AND INFORMATION ABOUT IRRIGATION ON THE PRAIRIES.

THE CONFERENCE THEME---IRRIGATION ON THE PRAIRIES---IS TIMELY. THIS YEAR, AND OVER THE LAST FEW YEARS, DROUGHT CONDITIONS IN PARTS OF SASKATCHEWAN AND THE PRAIRIES HAVE MADE THE DEMAND FOR IRRIGATION GREATER THAN EVER.

MORE

FARMERS REALIZE THAT WATER AND SOIL MANAGEMENT ARE CRUCIAL TO AGRICULTURAL SURVIVAL. YOU ARE HERE TO EXCHANGE INFORMATION ABOUT WATER AND SOIL RESEARCH AND MANAGEMENT PRACTICES. IRRIGATION IS ONE OF THESE PRACTICES. THUS THE INFORMATION THAT COMES FROM THIS CONFERENCE IS CRITICAL TO AGRICULTURE TODAY.

IRRIGATION BRINGS STABILITY TO THE PROVINCE'S GRAIN AND LIVESTOCK INDUSTRY. IT ALLOWS FOR DIVERSIFICATION INTO SPECIALIZED CROPS. IN THE LONG RUN, IRRIGATION STABILIZES THE PROVINCIAL ECONOMIES AND PROVIDES JOBS.

BUT FARMERS AND THE ENTIRE AGRICULTURE INDUSTRY AREN'T THE ONLY ONES WHO BENEFIT FROM IRRIGATION. THE SOCIAL AND ECONOMIC SPIN-OFFS THAT CARRY INTO THE COMMUNITY ARE NOT NORMALLY RECOGNIZED BECAUSE THEY ARE HARDER TO IDENTIFY AND THEN DEFINE.

MORE

- IRRIGATION ENHANCES COMMUNITY WATER SUPPLIES.
- IRRIGATION CAN PROVIDE INDUSTRIAL WATER SUPPLIES, HELPING TO
EXPAND THE BUSINESS POTENTIAL OF A COMMUNITY.
- IRRIGATION BENEFITS RECREATIONAL DEVELOPMENT.
- IRRIGATION FOSTERS SPECIALIZED COMMERCIAL AND SERVICE
INDUSTRIES.
- IRRIGATION LOWERS THE RISK OF LOSSES TO COMMERCIAL ACTIVITIES
BROUGHT ABOUT BY DROUGHT.
- IRRIGATION CAN INCREASE THE LOCATIONS FOR WILDLIFE TO FIND REFUGE
AND FEED SUPPLIES.

MORE

- IRRIGATION CAN MEAN MORE ATTRACTIVE AND PLEASANT

LANDSCAPE--FARMS CAN PRODUCE LARGE, ABUNDANT GARDENS; CITIES CAN

CREATE BEAUTIFUL PARKS.

- AND A MORE STABLE ECONOMY, BROUGHT ABOUT THROUGH IRRIGATION,

MEANS BETTER HEALTH AND EDUCATIONAL FACILITIES.

THE GOVERNMENT OF SASKATCHEWAN FOSTERS THE GROWTH OF IRRIGATION IN

THE PROVINCE THROUGH A GRANT FOR INDIVIDUAL AND GROUP PROJECTS

ADMINISTERED BY THE SASKATCHEWAN WATER CORPORATION.

MORE

HISTORICAL OVERVIEW

THE SASKATCHEWAN WATER CORPORATION HAS ATTRACTED A LOT OF INTEREST, IT REPRESENTS A UNIQUE APPROACH TO WATER RESOURCE MANAGEMENT IN NORTH AMERICA. PRIOR TO THE FORMATION OF SASK WATER ON JULY 1, 1984, THE MANAGEMENT OF WATER RESOURCES IN SASKATCHEWAN WAS TYPICAL OF THE REST OF CANADA AND THE UNITED STATES. WATER MANAGEMENT WAS A RESPONSIBILITY GIVEN TO VARIOUS GOVERNMENT DEPARTMENTS AND AGENCIES.

MORE

AS A RESULT OF THIS LONG-STANDING APPROACH, SASKATCHEWAN RESIDENTS TEND TO VIEW MATTERS INVOLVING WATER MUCH THE SAME AS ANYWHERE ELSE. FOR ONE THING, THE DEVELOPMENT OF WATER RESOURCES IS CONSIDERED TO BE A GOVERNMENT UNDERTAKING. FOR ANOTHER THING, WATER IS CONSIDERED TO BE A FREE AND PLENTIFUL RESOURCE.

PART OF SASK WATER'S MANDATE IN WATER MANAGEMENT WILL INCLUDE DEALING WITH THESE TRADITIONAL VIEWS. WE NEED TO ACHIEVE A BROADER UNDERSTANDING SO THAT DEVELOPMENT CAN BE EXPANDED, FOSTERED, AND ENCOURAGED, SO THAT WATER WILL BE VIEWED IN A DIFFERENT WAY -- AS A VALUABLE RESOURCE. ONE OF THE MOST DIFFICULT QUESTIONS IN THAT REGARD INVOLVES DEALING WITH THE QUESTION, "WHAT IS THE VALUE OF WATER?"

MORE

THE VARIOUS SYSTEMS AND APPROACHES TO WATER MANAGEMENT IN SASKATCHEWAN SINCE 1930 RESULTED IN A NUMBER OF SHORTCOMINGS:

(1) A LACK OF FIRM PROVINCIAL GOALS IN WATER MANAGERMENTS.

(2) RESULTS OF WATER DEVELOPMENT PROGRAMS WERE NOT ADEQUATELY ASSESSED.

(3) COMPREHENSIVE BASIN PLANNING WITHIN BROAD REGIONAL OBJECTIVES DID NOT OCCUR.

(4) WATER DEVELOPMENT PROGRAMS TENDED TO BE NARROWLY BASED.

MORE

(5) COORDINATION AMONG AGENCIES IN WATER MANAGEMENT WAS NOT OCCURRING; IT WAS SIMPLY TOO COMPLEX A TASK.

(6) PUBLIC INPUT WAS LACKING.

ON JULY 1, 1984, THE GOVERNMENT OF SASKATCHEWAN PROCLAIMED THE WATER CORPORATION ACT. AN ACT WHICH BEGAN A NEW APPROACH TO WATER RESOURCES MANAGEMENT AND ADMINISTRATION.

MOST SIMPLY PUT, THE GENERAL POWERS AND PURPOSES OF THE CORPORATION ARE:

MORE

1. TO MANAGE, ADMINISTER, DEVELOP, CONTROL, AND PROTECT

SASKATCHEWAN'S WATER AND RELATED LAND RESOURCES.

2. TO PROMOTE ECONOMICAL AND EFFICIENT USE, DISTRIBUTION, AND

CONSERVATION OF WATER.

3. TO MAINTAIN AND ENHANCE THE QUALITY AND AVAILABILITY OF WATER

FOR ALL PURPOSES.

IT IS A BROAD LEGISLATIVE MANDATE. THE ONLY THINGS RELATING TO

WATER NOT INCLUDED ARE THE ESTABLISHMENT AND ENFORCING OF

ENVIRONMENTAL AND HEALTH STANDARDS.

MORE

THE CORPORATION'S BROADEST GOAL IS:

"TO MANAGE AND DEVELOP THE PROVINCIAL WATER RESOURCE
FOR THE OPTIMUM ECONOMIC AND SOCIAL BENEFIT OF THE
PEOPLE OF SASKATCHEWAN."

FULFILLING THIS GOAL IS REFLECTED IN THE CORPORATION CONCENTRATING
ON IMPROVING ACCESS TO WATER AND QUALITY OF WATER. MORE THAN ANY
OTHERS, THESE TWO ASPECTS OF WATER MANAGEMENT AFFECT OUR ABILITY TO
ACHIEVE ECONOMIC GROWTH, TO INCREASE GENERAL PROSPERITY AND TO
IMPROVE OUR QUALITY OF LIFE.

MORE

WHY A CORPORATE STRUCTURE?

WHY A CROWN CORPORATION FOR HANDLING WATER MANAGEMENT? IT WAS RECOGNIZED THAT WATER RESOURCE DEVELOPMENT AND MANAGEMENT IS BOTH EXPENSIVE AND LONG TERM. IT WAS ALSO CONCLUDED THAT WATER MANAGEMENT NEEDS AN ORGANIZATION CAPABLE OF OWNERSHIP AND OPERATION OF WATER WORKS AND FACILITIES.

A CORPORATION'S FINANCIAL AFFAIRS ARE OF A CONTINUING NATURE RATHER THAN YEAR-BY-YEAR LIKE A LINE DEPARTMENT WITHIN GOVERNMENT. AS A RESULT, A CORPORATE ORGANIZATION IS BETTER EQUIPPED TO ESTABLISH AND CARRY OUT BOTH FINANCIAL OBJECTIVES AND COMPREHENSIVE PLANNING.

MORE

THE CORPORATION HAS BEEN STRUCTURED TO PROVIDE A UNIQUE BLEND OF:

1. ADVISORY AND POLICY SETTING FUNCTIONS.

2. CENTRALIZED TECHNICAL EXPERTISE; DECENTRALIZED ACCESS THROUGH
REGIONAL OFFICES.

3. COMPREHENSIVE PLANNING.

4. PROGRAM IMPLEMENTATION AT THE LOCAL LEVEL.

MORE

HOW HANDLED IN CORPORATE STRUCTURE?

TO HANDLE THESE VARIED ACTIVITIES, SASK WATER HAS FOUR MAIN DIVISIONS RESPONSIBLE TO A MINISTER, A BOARD OF DIRECTORS, AND A PRESIDENT.

THE FOUR DIVISIONS ARE:

1. WATERSHED MANAGEMENT
2. WATER SUPPLY AND UTILITY MANAGEMENT
3. RESOURCE MANAGEMENT
4. CORPORATE AFFAIRS

MORE

WATERSHED MANAGEMENT

DURING A SPECIAL CABINET COMMITTEE WATER HEARING IN 1983, MANY PRESENTATIONS EXPRESSED THE NEED FOR MORE LOCAL INVOLVEMENT. THE WATERSHED MANAGEMENT DIVISION ENSURES MORE LOCAL INPUT IN WATER RESOURCE DEVELOPMENT PLANNING. IT PROVIDES PUBLIC ACCESSIBILITY TO PROGRAMS BY REGION. THE PROVINCE HAS BEEN DIVIDED INTO SIX WATERSHED REGIONS, EACH WITH ITS OWN OFFICE. EACH OFFICE IS RESPONSIBLE FOR MANAGING, REGULATING, AND CONTROLLING THE WATER RESOURCES OF THE BASINS IN THEIR JURISDICTION.

MORE

THIS MANAGEMENT SYSTEM SPEEDS UP THE DECISION-MAKING PROCESS,
IMPROVES ACCESS, AND GETS MUCH NEEDED LOCAL INPUT AND KNOWLEDGE.
IT ALSO ENSURES THAT SASK WATER STAFF IS IN TOUCH AT ALL TIMES WITH
WHAT IS HAPPENING AT THE LOCAL LEVEL.

THESE REGIONAL OFFICES SERVE AS A FOCAL POINT. AT THESE OFFICES,
WATER USERS CAN OBTAIN APPROVALS TO CONSTRUCT AND OPERATE WATER
PROJECTS, OBTAIN TECHNICAL ASSISTANCE, FILE COMPLAINTS, AND OBTAIN
INFORMATION.

OF GREAT IMPORTANCE TO THE FUNCTIONING OF THESE REGIONAL OFFICES
ARE ADVISORY BOARDS IN EACH REGION. THEIR ROLE IS TO HELP THE
CORPORATION FULFILL ITS MANDATE.

MORE

COMPRISED OF INDIVIDUALS WHO HAVE A KNOWLEDGE AND APPRECIATION OF LOCAL WATER PROBLEMS, THE BOARDS PROVIDE FOR MORE DIRECT PUBLIC INPUT. IN THIS WAY, THE NEEDS AND INTERESTS OF THE PEOPLE CAN BE KNOWN AND DEALT WITH QUICKLY.

WATER SUPPLY AND UTILITY MANAGEMENT

ANOTHER AREA OF RESPONSIBILITY FOR THE CORPORATION ARE THE MAJOR PROBLEMS OF MUNICIPAL WATER SUPPLY AND SEWAGE EFFLUENT DISPOSAL. MAJOR FROM THE STANDPOINT THAT SOLUTIONS ARE OFTEN VERY COMPLEX AND COSTLY. MAJOR IN THAT ADEQUATE WATER AND SEWAGE SYSTEMS ARE CRUCIAL TO THE ECONOMIC GROWTH AND STABILITY OF OUR CITIES AND RURAL CENTRES.

MORE

TO DEAL WITH THE IMPORTANT RESPONSIBILITIES OF MUNICIPAL WATER AND SEWER AND REGIONAL UTILITIES, THE CORPORATION HAS THE WATER SUPPLY AND UTILITY MANAGEMENT DIVISION UNDER THE DIRECTION OF A VICE-PRESIDENT.

SOME OF ITS WORK DEALS WITH OVERCOMING SIGNIFICANT WATER QUALITY PROBLEMS. OTHER WORK INVOLVES SERVING SEVERAL COMMUNITIES AND/OR INDUSTRIES FROM A SINGLE SYSTEM. THIS CREATES THE NEED FOR REGIONAL WATER UTILITIES.

PRIOR TO THE FORMATION OF SASK WATER, THE WATER SUPPLY UTILITIES IN SASKATCHEWAN WERE HANDLED BY THE SASKATCHEWAN WATER SUPPLY BOARD. IT IS NOW PART OF SASK WATER.

RESOURCE MANAGEMENT

A THIRD DIVISION OF THE CORPORATION IS CALLED RESOURCE MANAGEMENT.

IT PERFORMS MAINLY SUPPORT AND PLANNING FUNCTIONS.

IT GIVES THE CORPORATION SPECIALIZED TECHNICAL ASSISTANCE AND OTHER
SUPPORT SERVICES. IT PROVIDES COMPREHENSIVE BASIN PLANNING AND
MANAGES INTERJURISDICTIONAL WATERS.

REPORTING TO A VICE-PRESIDENT, RESOURCE MANAGEMENT OPERATES TWO
MAIN BRANCHES -- ENGINEERING AND PLANNING.

MORE

CORPORATE AFFAIRS

THE FOURTH DIVISION OF THE CORPORATION IS CORPORATE AFFAIRS. IT HANDLES PUBLIC AFFAIRS, ADMINISTRATION AND PERSONNEL, ACCOUNTS, AND BUDGETS. A CONTROLLER OVERSEES THE WORK OF THIS DIVISION.

LONG-RANGE POLICIES

THE CORPORATION'S LONG-TERM POLICIES RELATE TO THE MANAGEMENT PLANS TO BE PREPARED OVER THE NEXT 8-10 YEARS FOR EACH OF SASKATCHEWAN'S MAJOR RIVER BASINS.

MORE

AT THE PRESENT TIME, THE SOUTH SASKATCHEWAN RIVER BASIN IS THE FIRST PRIORITY. IN THIS BASIN, LAST YEAR'S LOW WATER LEVELS HAD A TREMENDOUS IMPACT. IT SEVERELY RESTRICTED THE ABILITY OF FARMERS TO IRRIGATE, THE SASKATCHEWAN POWER CORPORATION'S ABILITY TO GENERATE POWER, AND OF COURSE, HAD A NEGATIVE IMPACT ON WATER-RELATED TOURIST AND RECREATIONAL ACTIVITIES.

THESE COMPREHENSIVE BASIN PLANS WILL FORM THE FOUNDATION FOR EFFECTIVE AND EFFICIENT MANAGEMENT PLANS FOR ALL ASPECTS INVOLVING WATER.

MORE

SASK WATER IS BASED ON THE PREMISE THAT WATER IS A NATURAL RESOURCE THAT NEEDS TO BE MANAGED FOR THE BETTERMENT OF SOCIETY. TO THAT END, THE ASSOCIATED MANAGMENT AND DEVELOPMENT COSTS WILL HAVE TO BE FAIRLY ALLOCATED. JUST HOW THAT MAY BE DONE WILL, NO DOUBT, REMAIN A CONTROVERSIAL TOPIC. THE ECONOMICS OF THE DEVELOPMENT AND USE OF WATER RESOURCES WILL REMAIN A CHALLENGE TO THE CORPORATION FOR YEARS TO COME.

IRRIGATION DEVELOPMENT WILL CONTINUE TO BE A TOP PRIORITY FOR BOTH THE CORPORATION AND THE GOVERNMENT. WE PLAN TO FOCUS OUR EFFORTS AND FINANCES ON MAJOR EXPANSION AND DEVELOPMENT OF THE AERABLE ACRES IN OUR PROVINCE.

MORE

LAST YEAR, THE NEWLY-ESTABLISHED SASKATCHEWAN WATER CORPORATION SUPPLIED MORE THAN 22,890 ACRE FEET OF WATER TO THE DEPARTMENT OF AGRICULTURE FOR IRRIGATION PROJECTS.

MORE THAN \$200,000 IN GRANTS WERE PROVIDED TO SEVEN DIFFERENT GROUPS TO DEVELOP, MAINTAIN AND OPERATE IRRIGATION WORKS. MORE THAN \$100,000 WAS PAID TO THE SOUTH SASKATCHEWAN RIVER IRRIGATION DISTRICT.

MORE

THE DEMAND FOR INDIVIDUAL IRRIGATION ASSISTANCE WAS LOWER BECAUSE OF THE DIFFICULT AGRICULTURAL ECONOMIC CLIMATE. SASK WATER HANDLED 84 NEW APPLICATIONS AND PROVIDED SERVICES TO 102 PROJECTS UNDER THEIR PROGRAM FOR ENGINEERING AND FINANCIAL ASSISTANCE FOR INDIVIDUAL PROJECTS.

SASKATCHEWAN HAS GREAT POTENTIAL FOR IRRIGATION DEVELOPMENT. A RECENT STUDY IDENTIFIED UP TO 4.2 MILLION ACRES OF SASKATCHEWAN LAND SUITABLE FOR IRRIGATION DEVELOPMENT.

MORE

FARMERS MUST ACQUIRE THE FULLEST KNOWLEDGE ABOUT IRRIGATION IN ORDER TO TAKE ADVANTAGE OF THIS OPPORTUNITY. THIS CONFERENCE IS A VITAL STEP IN FILLING THIS NEED. BUT THERE ARE OTHER CONSTRAINTS.

- VARIABLE MARKET CONDITIONS OFTEN MEAN FARMERS CAN'T AFFORD TO BE ADVENTUROUS. IT SHOULDN'T SURPRISE US IF A FARMER WANTS TO STICK TO TRIED AND TRUE FARMING METHODS IN TODAY'S UNPREDICTABLE ECONOMIC CLIMATE.

- INCREASED FINANCING COSTS DUE TO SUCH FACTORS AS MECHANIZATION, AND ADVANCING TECHNOLOGY.

MORE

- THE PRESENT QUOTA SYSTEM DISCOURAGES INTENSIVE CEREAL CROP PRODUCTION.

- MARKETS FOR SPECIALTY CROPS SUCH AS SUGAR BEETS, VEGETABLES AND FORAGE ARE LIMITED AND UNSTABLE. THESE MARKETS WILL NOT DEVELOP UNTIL WE HAVE A GUARANTEED SUPPLY, AND TRANSPORTATION AND PROCESSING FACILITIES.

MORE

DESPITE ALL THIS, THE INTEREST IN IRRIGATION REMAINS HIGH. I
BELIEVE ALL THESE DIFFICULTIES CAN AND WILL BE OVERCOME. THE
ECONOMIC BENEFITS ARE JUST TOO GREAT FOR US TO LET THEM SLIP BY.
THE CHALLENGE IS THERE.

IT'S A QUESTION OF COMMITMENT---COMMITMENT FROM THE GOVERNMENT AND
SOCIETY; COMMITMENT FROM THE FARMER AND COMMITMENT FROM THE
RESEARCHER.

THIS CONFERENCE IS A SYMBOL OF THAT COMMITMENT.

THE END

PUBLIC IMAGE OF IRRIGATION

Ron Larson
Editor, Irrigation Age Magazine

More people know less about irrigation today than ever before. For, in the United States, national weekly news magazines have run cover stories which depict the States as becoming dry, parched earth. Agriculture accounts for 85% of the water used in the nation every day -- and irrigation is the major reason for that high a percentage. So irrigation gets a lot of editorial attention in these articles ... but seldom is it positive.

The irrigator is the most highly-visible member of an industry which generally hopes to keep a very low profile in our society. Only recently have farmers in the United States sought to draw attention to themselves, and that's because our agricultural economy is in rather dismal straits. Our farmers are finding it difficult to keep an optimistic perspective about their future in agriculture.

The question I'm most often asked as I travel around the States is, "What will you (meaning those of us who are directly connected with irrigation) do when there is no more water?" The question is well-meant, but it shows the impact of a considerable amount of adverse publicity about the condition of water throughout the United States. For America as a whole, the future supply of water is not a problem. The problems are possible large-scale contamination of our water supply, and providing sufficient water supplies for areas of the country that have no resident supply, or are rapidly running out of water. But we wouldn't know that from the publicity surrounding our water problems.

The most recent national publicity has been over a relatively obscure reservoir in north-central California. The Kesterson Reservoir, which was built many years ago to catch irrigation return flow from the surrounding farm land, suddenly sprang into the national spotlight about a year ago, when the U.S. Department of the Interior ordered it closed to further irrigation return flows. The reason was that over a period of about 25 years, the salt-laden irrigation flows had been depositing what is now a near-lethal amount of selenium in the reservoir. Waterfowl that used the reservoir as a resting and feeding area were dying or being maimed by the effects of selenium poisoning.

Approximately 40,000 acres of irrigated farmland are affected, and the resulting national publicity laid the blame at the doorstep of irrigators who were attempting to make a living from land which would grow very little without irrigation. The reservoir was, after all, doing exactly what it was designed to do, catch salt-laden return flows from the irrigated fields. Unfortunately, waterfowl had taken a liking to the reservoir, as well. And, what was happening to the waterfowl as a result of the intake of selenium, brought the wrath of environmentalists. They wondered, too, about possible effects on humans.

The bickering between environmentalists, farmers and government officials has continued for several years. At one point, the Department of the Interior made unsuccessful efforts to try and scare the birds away from the reservoir.

The birds refused; the environmentalists became more indignant, and finally the decision was made to close the reservoir. But that meant putting the farmers virtually out of business because there was no place for their irrigation flows to go. The closing, however, was delayed a year, as additional efforts are made to find a solution that will allow farmers to continue growing crops. While different solutions are sought and tried, nothing will erase the original implication from the minds of the general public, that irrigators were trying to poison their neighbors and wildlife with these return flows into the Kesterson. The damage to irrigation's public image was extensive, to say the least.

Accumulation of salts in irrigation water is a problem throughout the southwestern United States. Salt buildups affect many thousands of acres. In some cases, through improper irrigation management, these salts have risen to the top of the soil and made the land unfit for growing crops. The salt-laden Colorado River caused a diplomatic rift with Mexico, our neighbor to the south. It was resolved by the U.S. government spending several billion dollars to build and operate a reverse osmosis desalinization plant which still will handle only about one-quarter of the flow of the Colorado River where it enters Mexico.

We are finding that changes in irrigation techniques, and structural changes such as concrete lining of irrigation canals and ditches appear to offer a more permanent solution to

the problem, at less cost. However, for diplomatic reasons, the U.S. government was looking for a quicker and more dramatic solution to the problem. So taxpayers paid for an expensive desalinization plant with limited capacity. At least we made the Mexicans happy.

We also are seeing the effects of nitrates from fertilization showing up in well water in certain parts of the country.

Nitrates which have been leached into the groundwater -- either because of rain, or irrigation -- have shown up in wells in Nebraska, Illinois and some other midwestern states. These reports also gain wide attention because of residents who are depending upon well water for their drinking supply. If there is irrigation in the area, it's automatically assumed that the irrigator is at fault. But recent research indicates that nitrates may not move as quickly into groundwater supplies as originally thought. In some cases, it may have been abuses of 20, 30, or 40 years ago that have resulted in contamination of groundwater supplies by nitrates. Feedlot operations also are an excellent source of migrating nitrates.

During that time, farmers have learned a lot about the use of fertilizers. They've learned, particularly, that more is not necessarily better, that application management is important to keep the nitrogen in the root zone where the plant can use it, and that effective application management can result in better yields with less fertilizer -- which certainly doesn't hurt the pocketbook. Still, the public image remains that

irrigators are the type to pour too much fertilizer on their crops, and then flush that fertilizer down into the groundwater with their irrigation rigs. It matters not that the irrigator may have reduced his nitrogen application. The average citizen isn't aware of the research on proper timing of fertilizer applications that has been done, and what the irrigator is doing to get more effective use of fertilizer and cutting his production costs. That's not exciting national news.

Now let's bring the problem a little closer to home for you. Almost directly to the south of us is the currently-controversial Garrison Diversion Project in North Dakota. The project --originally envisioned 40 years ago and an outgrowth of the Pick-Sloan Project which placed dams on the upper Missouri River -- is still embattled. It, like the Colorado River problem, has had international ramifications. You know of opposition here, and it's opposed by some in the States. You'll hear more about it tomorrow.

So far, I've talked about contamination and pollution of surface and groundwater, the negative public image that has resulted from it. But there's probably even greater public concern about the future availability of water in the United States. Here again, the irrigator is the object of major finger-pointing.

Probably everyone here has heard of the Ogallala Aquifer. Most Americans may not be able to pronounce it, but they've heard of it. The Ogallala is one of several major aquifers underlying the United States. Unfortunately, portions of it have been in danger of being pumped dry. There's been plenty of press about that, too. Commissions have studied the

Ogallala, and the subject has been discussed in Congress. In the meantime, however, researchers and irrigators have been working together to find ways of stemming the outflow of water from the aquifer. In some areas, the mining of water from the aquifer has been reduced to almost a point of equilibrium, but very few people in the country are aware of this work. Most believe that the Ogallala will soon be a dry underground lake, and there will be no more water to drink. That, of course, is not true.

To those of us who follow the situation closely, it seems terribly unfair that many Americans remain hopelessly uninformed about what is being done to correct past abuses and to assure that there will continue to be adequate water supplies for future generations. Most Americans, apparently, are just expecting to turn on their faucet and find that there's no water coming out of it. Let me just mention a few things that are being done to extend the useful life of the Ogallala. While irrigation districts throughout the area have imposed restrictions on the number of wells that can be drilled and the amount of water that can be withdrawn, researchers have been working with farmers, showing them ways of cutting back on water usage -- and still being able to grow a good crop. They've also discovered that there is a lot of water trapped in layers of sand which until recently couldn't be tapped. However, technology from the oilfields has been converted to use in irrigation areas--shooting air into the wells frees the water from the sand -- and, it's not all that expensive to do.

Irrigators in the water-starved southwest (Arizona and Southern California, in particular) find themselves in direct conflict with urban dwellers who have taken up residence in areas which were not designed to be habitable. Now, people in those areas must depend upon snowmelt in the mountains ... which flows through a system of canals for their survival. That kind of situation can lead to gunfights, when someone feels that someone else is tampering with his or her right to water.

Obviously, the farmer's need for water to grow crops is not a big priority for an urban dweller who is afraid he won't have water the next time he opens his tap. Growing populations in these water-short areas put additional pressure on limited water resources. Even though there are warnings that the present water supply won't suffice, taxpayers do not want to spend the tax dollars to expand water delivery systems. Instead, each group of users proposes that the other groups cut back. Irrigators do not have the clout to survive a battle like that.

The huge surpluses of major crops that are being built up by American farmers are the third aspect of the public image problem.

As surpluses grow, more fingers are pointed at irrigators. Irrigated land represents about 12 to 15% of the total crop acres in the U.S., but those acres account for over 25% of the production. What people don't realize, however, is that the irrigated acreage represents a stable core of our overall production, keeping us from facing a shortage in the case of major drought.

Those are acres we can rely upon under almost any conditions during the growing season. Irrigation also gives growers the versatility to grow many different crops. Often, that can mean the difference between a profitable operation and bankruptcy. So the point of all this is that the fact that a farmer is an irrigator doesn't necessarily mean that he is a major contributor to over-production of a crop like corn or soybeans. The smart irrigator will be looking at a diverse cropping scheme that will take him out of the local mono-crop competition.

The purpose of this report is not to be negative, but to try to make an objective appraisal of the problems that irrigators, and members of the industry, have to face. It would be unrealistic to think that everyone sees the benefits of irrigation, when, in fact, he or she doesn't. As irrigators become more proficient at their work, expanding technology will lead them into other troublesome areas. For example, more and more American irrigators are recognizing the efficiency and cost-saving of applying chemicals through their irrigation systems. I'm sure this is a growing trend here in Canada, as well. This has led irrigators into further confrontations with environmentalists, who would prefer that farmers go back to farming as they did 100 years ago. Agricultural chemicals are an important and necessary part of modern farming operations. No one knows better the hazards of mis-use of chemicals than does the farmer. He's going to be the first one affected. But he finds himself defending his actions to those who could care less whether he is able to survive in his chosen occupation.

Don't misunderstand ... concern for our environment is important. However, there are those who are promoting their own interests under the guise of being concerned about the environment.

Those who work with irrigation every day know its benefits. They are good stewards of their land, and of their resources. This year, for example, six of the ten finalists for national soil conservation awards in the States are irrigators. I'm fully confident that historians 100 years from now will see the irrigation development of this century as one of the major, positive aspects of continued agricultural growth in our country.

However, the irrigator will have to be an optimist, and irrigators everywhere are going to have to take leadership in attacking problems that may give their industry a bad image. It's in their own best interest to do so.

IRRIGATION PROSPECTS AND PERSPECTIVES

V. C. Prudek

It is a pleasure to address this Conference -- I thank you for the kind invitation. I don't profess to speak for all irrigation farmers, but welcome the opportunity to share my thoughts with you on this important subject. If my remarks are abrasive or offensive, I apologize in advance. I believe that in Conferences such as this, one should speak most frankly. The problems facing agriculture, and specifically irrigation, are far too important to be treated in a casual or blasé manner.

I would like to share with you my concerns, observations, and most important, my hope for the future. Because of the complex nature of our society, the powerful special interest, the disarray in our economic and monetary system, the general attitude of the populace, and misplaced priorities in government, this may not allow the development of an Agriculture system of the type which I envision. However, it is clear that the present system which was built on the premise of plentiful, cheap, resources is no longer viable.

Last spring on a desert entry farm in southern Idaho, a well informed farmer said to me, "If there isn't a cheaper alternate energy source or a more efficient irrigation system developed soon, this land will all revert to desert." Recently another farmer in the Columbia Basin of Washington on gravity irrigated land said, "I have always financed my farm operation and I may squeak by this year by not replacing my machinery, but the hand writing is on the wall." Many of us have known for a long time that the change in supply of resources would result in the crisis that we are now experiencing. There was warning lights flashing in many places of this impending crisis -- yet to

a large degree we ignored or were helpless to do anything about it. The solution was bigger is better, and most swallowed it hook, line, and sinker. Little or no attention was given to conversion efficiency. Through this period of time, the common theme of most economists was bigger farms, fewer farmers - small margins on a large volume was the path to riches. What utter nonsense if you have any regard for conversion and conservation of resources, not to mention reliability of production. To expect to improve viability by making an industry more dependent upon an energy resource coming progressively into shorter supply must be the ultimate in deficient wisdom. Certainly, the liberalism which encouraged bizarre human behavior by great emphasis upon individual rights without equal emphasis on responsibility and duty to society added to the problem for it forced over capitalization. Further, we must not ignore the production which was brought on stream by purchase of our own production with our own money as a result of Western Governments guaranteeing loans by Western Banks to East Europe and Third World Countries. The unfortunate results was a major cause of the demise of Western Banking. (Source -- Pierre Solinger Report, August, 1981, Paris - World Monetary and Economic Crisis, also Ambassador Romecz, Poland to Japan, - Buckley Interview - 1981). Thus, the major cause of current farm crisis in North America is the direct result of extraordinary incompetence by Western Governments and Banking Institutions.

There can be no question that North American agriculture must be rebuilt to restore that revenue which was transferred off of the farm as a result of these events. Naturally, given the sorry state of monetary and economics -- nationally and internationally, economic and monetary reform must be the first order of business. Without this, trade upon which North American agriculture

depends so heavily will become more difficult and unreliable.

EFFICIENT CONVERSION OF RESOURCES

Secondly, the efficient conversion of resources must be the next consideration in the rebuilding process. The profit margin must be approximately 100% of hard cash costs excluding depreciation and selling costs. This is quite typical in many forms of manufacturing and can go up to 200 - 300% in certain fields (clothing). A Farmer is a manufacturer of food. He should be extended the same courtesy for the vital importance of his contribution to society.

SYSTEMS OF TOMORROW

Now how do we accomplish this? If one looks back to the change from horse power to tractor power, it required over a decade to make the transition. One would expect this transition period to be very similar and much more impressive.

DEFICIENCY

Presently, all irrigation systems have serious deficiencies. The same is true of all tillage systems. Because of regional differences and crops, no single system can be expected to work efficiently in all areas. Rather, systems will have to be developed which will hopefully:

1. Be not less than 90% efficient.
2. Apply water into the soil to prevent heat suppression and surface evaporation.
3. Maintain a dry surface to lower incidence of plant disease (i.e. Rust, Mildew, White Mold, etc.)
4. Are highly reliable.
5. Require little or no energy input.
6. Uniform application - plus, minus 5%.

7. Operational life 25 years plus.
8. Adequate application capacity.
9. Low operation and maintenance costs.

The system I have described is similar to a buried drip line system which is currently being developed in Arizona. I would rather call the system an enclosed sub-irrigation system. Such a system was initially investigated by German and Fishbeck in Nebraska. Others also have shown an interest in this type of irrigation. Because of orifice plugging by Bacteria, their effort was not successful. However, the Arizona project of initially some 2,000 acres of cotton and wheat seems to be over-coming these problems. Indications are that not only is water conversion improved, the same is true for fertilizer and herbicide needs. In addition, as this system is refined, production should increase 20 - 50%. Currently it would appear that reduced inputs plus increased yields and extension of water resource makes such a system not only feasible, but also viable. As my current system loses it's viability, I would like to replace it with a system of this design. The primary reason for replacement would be increased viability by heat enhancement, disease reduction, and reduced water costs. Because such a system is buried 11" to 12" deep at 38" spacing, precise tillage is very important. Obviously a wheel tractor that is spinning could easily damage such a system in a wet spot, which brings us to the subject of tillage.

TILLAGE AND IRRIGATION

Our current concept of power application for tillage is direct ratio of weight to draw bar pull. Thus, the greater the pull, the greater the weight. I estimate the conversion of energy to useful work at 20 - 25%. Most of the loss is in the transportation of this enormous weight over our fields and the

harm that results from the compacting of moist soil and the loss of water resource and soil production potential. Our current tillage concept in this age of technology is about as sensible as a modern Jet Airliner made of cast iron having a good pay load conversion ratio. We must develop a self-propelled Ag Carrier tillage concept that is propelled by penetration of the soil and is light weight in design. The tillage tools must be of a self-sharpening design to reduce the sled runner compaction that results from current tools. We should be able to reduce our current energy requirement for tillage to approximately one third of the present consumption. At the same time we should realize a production increase of from 10 - 20%. I would envision this machine being powered by Diesel, Electric, or Diesel - Hydraulic. However, the potential for Hydrogen - Electric and or Hydraulic should not be discounted. This would be most desirable environmentally and economically, if the Hydrogen was generated by Electrolysis from wind powered generators on our farms.

PRESENT NEEDS

As for what can be done now to optimize farm income, the options are quite limited. A highly disciplined use of a production package is a must. As an example, 100 bushels per acre of soft wheat is still profitable and this can, and is being achieved consistently by some producers. The same performance applies to other crops such as Canola, Beans, and Corn. These production packages must be carefully planned and executed.

CONCLUSION

I recognize that what I suggest may appear far out - but so was the change from horse to tractor. Granted, there will be over production which will require a return of land base to reserve natural state to balance production and

demand. This is a challenge for responsible government which will put agriculture on par with industry and is very important to our total society. The policy of using agriculture to stimulate industrial activity without regard to the consequences of this action can no longer be tolerated. In spite of the current dilemma, I see a bright and efficient era for irrigation in the future. My only regret is that I cannot turn the calendar back thirty years so I might enjoy it more fully in the prime of youth. Granted, the challenge is great, but so is the technology and resources at our disposal.

We can build a more efficient irrigation and agricultural system. If we are to sustain a stable, good society, if we want to leave a legacy we are proud of, then the choice is very clear. Lets get to work - now.

Thank you for your kind attention.

V. C. Prudek

SESSION I

The Soil and Water Resource

Chairman: J. F. Danyluk

IRRIGATION ON THE PRAIRIES - 1985

November 26, 1985

Presented by Harvey A. Fjeld, Director,
Saskatchewan Agriculture, Irrigation Branch
to the Fourth Annual Western Provincial Conference
Rationalization of Water and Soil Research and Management
Saskatoon, Saskatchewan

INTRODUCTION

What about Irrigation and Agriculture?

This conference offers a real opportunity to take a good look at the factors influencing irrigation and how our actions influence irrigation.

Irrigation is such a natural part of agriculture it has no recorded beginning. Plants, the principal source of food, need a proper climate and three major elements: soil, water, and air. Of these, of course, water is in shortest supply.

The ultimate source of water on land is precipitation. The variation of independent climatic variables of precipitation, heat, wind, soil temperature, frost periods, together govern the type and yield of natural plant growth. These climatic elements fluctuate widely within and between the agricultural regions of the prairie provinces.

Irrigation, the act of artificially applying water, is one of the oldest known agricultural technologies. In arid and semi-arid regions if one is to optimize production, water must be applied artificially. Irrigation is a substitute for precipitation, not a substitute for management.

WHAT DOES IRRIGATION OFFER?

The stability and benefit of two to four times the average yield is dramatic and explains why a farmer invests in irrigation in drought-prone regions. In more humid areas, production of higher value crops on lighter soil have competed effectively with the same crop on heavier soils. The above statements should not be interpreted to mean irrigation is an automatic success for all farmers. Irrigation is management and should not be entered into without careful economic and financial planning.

Farmers are not the only ones to benefit from irrigation development. The act of using water creates inputs and activities in almost all sectors of the economy that result in more employment, investment opportunities and more taxes.

The most obvious direct beneficiaries of irrigation development are the farmers. Livestock and crop production are stabilized and diversified. Other direct beneficiaries include the agricultural supply industry, the agricultural product industry, and a variety of sporting and water-based recreational industries. The direct benefits result in increased economic activity with more employment, investment opportunities and more tax revenues in our communities, province and country.

Irrigation development also creates indirect opportunities for the agricultural processing sector. The opportunities result from the potential increased variety of product coupled with increased stability of supply. The activities in these industries such as purchasing, producing and marketing, result in further increases to economic activities with even more employment and investment opportunities, with more household purchases and more tax revenues.

A 1984 study by Underwood McClellan Ltd. distributes the benefits from Alberta irrigation as follows:

Water Users.	.14.89%
Alberta Economy.	.66.09%
Rest of Canadian Economy	.19.02%

Since 1940, western governments and Canada have recognized the value of public investment in irrigation to promote economic growth where water flows and benefit cost analysis warrant. Many communities owe their existence to irrigation, for example, "Where would Lethbridge be without it?" The Agrologists of Alberta boast 20% of Alberta's total agricultural production is from the approximate 4% of improved land that is irrigated.

LAND AND WATER ISSUES

Water Issue

The theme of the recently commissioned water inquiry by Environment Canada was that water resources are becoming strained at the present level of use. Recent resource development papers of British Columbia, Alberta, Saskatchewan, and Ontario, also agree that water availability is the limiting factor to irrigation expansion. But there is vast disagreement in the order of millions of hectares, as to the potential irrigated land that our limited water supply can serve.

To me the real question is how much of the flow do we attempt to use to our benefit? Is it 5%, 25%, 50% or what percentage? What should our management strategy be?

The key to understanding the different viewpoints and potential water available are both philosophical and economical. The philosophical difference lies in the lack of agreement as to the benchmark flow to use to regulate water use. The criteria of some assigns a high regard for natural flow. They use "reliable flow" or two consecutive dry year flows. On the other extreme some advocate total basin control and basin transfers to avoid restriction to annual mean flow.

The economic difference of viewpoint centers on the method of determining economic resource use. Again, there appears to be general agreement with the need for economic benefit cost analysis to justify resource development.

However, the methodology is sufficiently complex that many different models and different criteria for the models can be employed at the satisfaction of the user. There is no intent, here, to discredit the use of benefit cost analysis, but it is a very powerful tool, which without careful input estimation can be very misleading.

Soil Issue

Many of the same things said about the water issue do apply to the land, however, the land issue has different view points as a result of classification conflicts when considering land use, specifically dryland or rain fed production versus irrigation and the artificial application of water.

This issue is a complex issue and I wait with anticipation for the presentations and the discussion periods on these topics.

Soil-Water Issue

If there is a major concern with land and water use and classification it is where soil-water compatibilities have not been specifically considered on the merits of the soil quality available and water quality available for irrigation.

If we are to be serious about resource use and management, soil-water compatibility must be a requirement before authority is given to operate irrigation projects on an individual or group basis.

Irrigation demands that its followers have more than a single thought path and to view it from more than one perspective, however, for the duration of the conference I would like to think of irrigation from at least the perspective of "on the other hand."

Some examples are:

1. Intensive Irrigation . . .versus. .Non-Intensive Irrigation
2. Full Irrigation. versus. . Supplemental Irrigation
3. Poor Quality Water versus. Good Quality Water
4. Private Development. . . .versus. Public Development
5. Growing a Crop versus. Marketing a Crop
6. Light Soils. versus. Heavy Soils
7. Low Pressure Application .versus. High Pressure Application
8. Crop Experience. versus. .Processing Opportunities
9. Security of Hard Wheat . .versus the risk of. .Soft Wheat
 . .versus the risk of. . . .Canola
 . .versus the risk of. . .Potatoes
 . .versus the risk of. . .Lentils
 . .versus the risk of. .Sunflowers
10. Major Project. versus. . . .Individual Project

Irrigation has in the past years been raised more into public view; however, more often than enough the strong or good aspects are forgotten or not mentioned and weak and negative aspects are focussed on by the media and those who have very narrow experiences with irrigation.

Irrigation is growing in western Canada, it will continue to grow and the constraints that face us have to be addressed in a rational manner that benefits farmers, rural development and society as a whole.

Since irrigation is going to be successful we must emphasis resource use. Identify what is good and be proud of it and identify what still requires refinement and get at it either co-operatively or individually.

We should never stop asking questions and searching for solutions, for in that process we plot our future.

Thank you and have a great conference.

IRRIGATION WATER QUALITY-SOIL COMPATIBILITY

GUIDELINES FOR SASKATCHEWAN

D.R. Cameron, NORMAC A.E.S. Ltd.

There are a large number of variable factors and factor interactions that play a role in irrigation. Factors such as salinity of the irrigation water, types of cations and anions present, physical composition of the soil, interaction of the irrigation water with the soil chemistry, salt tolerance of the crop being irrigated, leaching fraction, climate of the area, type of irrigation system, and level management all play important roles. The presence of specific ions, toxic compounds or elements, microorganisms, and pesticides must also be considered.

A. SOURCES OF IRRIGATION WATER

There are three general categories of water which have potential use for irrigation on agriculture land. The three categories of water include:

1. Surface Water - most common
2. Groundwater - increasing useage
3. Effluent Water
 - (a) Municipal - increasing useage
 - (b) Agriculture - rare
 - (c) Industrial - rare

In Saskatchewan, surface waters account for almost 100% of the irrigation waters used. Surface waters include waters from rivers, reservoirs, sloughs, and spring-runoff (backflood irrigation). Irrigation from groundwater sources is in its infancy. Many of Saskatchewan's bedrock aquifers tend to be highly mineralized and their waters may not be suitable for irrigation except under certain conditions.

There is increasing pressure for the use of agriculture land for disposal of secondary lagoon effluent waters. The idea of disposing of some industrial wastewaters (canneries, milk processing and malting plants) is being considered. These "new" and "exotic" sources of water have caused some changes in our thinking with regard to irrigation water quality guidelines.

B. OBJECTIVE AND PHILOSOPHICAL FRAMEWORK

Often water quality guidelines for irrigation have been developed assuming that the water is being applied to a well drained soil under an ideal irrigation management system. Similarly, land classification criteria for irrigation have often been developed assuming the use of good quality water. In this report we make a first attempt to reconcile water quality with some soil properties, and determine guidelines which merge the complementary factions into overall suitability or compatibility criteria. The primary objective is to provide a comprehensive set of guidelines for soil and water quality for use in irrigation projects in Saskatchewan. These guidelines apply to water from a variety of sources including surface waters, groundwaters, and wastewaters for application on agricultural lands.

The philosophical framework for the development of these guidelines can be summarized as follows:

"Saskatchewan soils are a valuable agricultural resource whose productivity can often be enhanced by irrigation. While irrigation can provide the benefit of increased productivity, it can also damage the soil if the irrigation water quality is not compatible with the soil. The purpose of these guidelines is to maximize the benefits associated with irrigation with various water categories while minimizing any potential risks to soil degradation. It is also the intent of these guidelines to ensure that agricultural lands benefit from irrigation and do not become dumping sites for undesirable elements and substances."

C. SASKATCHEWAN GUIDELINES

1. Salinity and SAR Guidelines for Saskatchewan (Cameron 1985).

<u>Soil Texture</u>	<u>Maximum Allowable Salt Concentrations</u>		<u>Maximum Adjusted RNa Of Irrigation Water</u>
	<u>EC(mS/cm)</u>	<u>mg/L</u>	
Loamy sands and sandy loams	4.0	2800	16
Loams, silts and silt loams	2.5	1750	12
Sandy clay loams, silty clay loams, and clay loams,	2.0	1400	10
Silty clays, sandy clays, and clays	1.5	1000	8

Considerations

1. It is assumed that the soils to be irrigated are considered to be well drained for their texture class, not having slowly permeable strata or shallow water tables.
2. At the higher salt concentrations, selection of more salt tolerant crops may have to be made.
3. The maximum SAR have been restricted to provide a safety-factor until more knowledge of the EC - SAR relationship in field situations under Saskatchewan conditions is obtained (see Figure 1 for rainfall protection criteria).
4. Higher salt loading and waters with higher SAR's can be used on pure sands, but the potential for groundwater contamination should be examined.
5. Where source waters exceed 1000 mg/L dissolved salt concentration, a site-specific soils-shallow hydrology investigation should be made prior to long term use of such waters for irrigation.
6. Average texture of the soil should be measured in the 0-1.2 m profile.

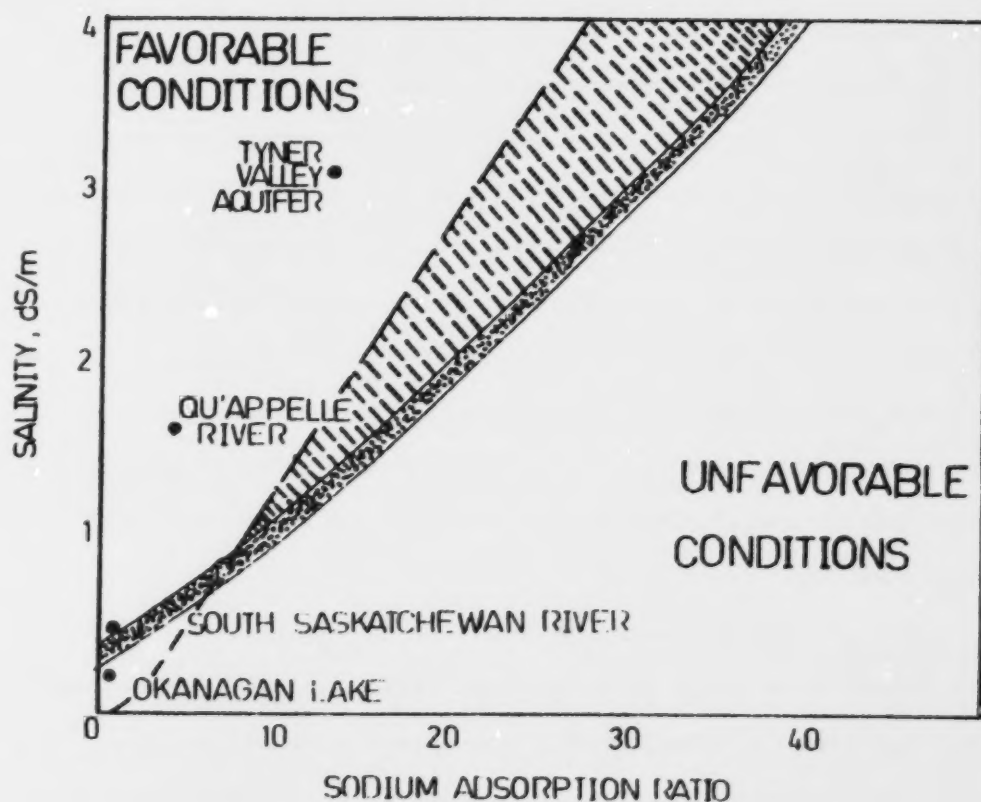


Figure 1. Relationship between irrigation water salinity and sodium adsorption ratio showing favorable and unfavorable conditions. The cross-hatched area provides a further use restriction for climatic areas where rainwater or snow meltwater can leach and dilute the surface salt concentration without affecting the exchangeable sodium percentage.

2. Drainage Criteria

There are a large number of factors that interact to influence "drainage". In most irrigation projects, internal drainage becomes an important controlling factor. It refers to the rate of removal of water from the rootzone through the soil and shallow groundwater system.

In any irrigation assessment, drainage must be considered as a 3-dimensional criteria. As such, factors like texture, geological uniformity (uniformity of permeability), intake rates (infiltration, percolation), depth to water table, salinity and sodicity, presence of slowly permeable strata, topography, average local relief, presence of depressions, hummocky terrain, potential fringe area impacts, spatial variability of hydraulic conductivity, and soil structure must all be considered. The effect of all of these factors on water table levels and drainage over the fourth dimension, time, must be carefully evaluated.

The ultimate expression or indicator of "drainability" is reflected in the depth to water table. All the above mentioned soil and landscape factors ultimately have an influence on the local groundwater regime and, thus, the ability of an irrigation site to remove the groundwater away from the area.

For irrigated agricultural lands in Saskatchewan it is recommended that local water tables must be maintained sufficiently deep as to prevent salinization of the irrigated area as well as prevent any potential harmful impact on non-target non-irrigated fringe areas (including contamination of any domestic groundwater wells or surface water supplies).

For most areas in Saskatchewan, it is recommended that "equilibrium" water tables should be maintained at a depth greater than 2 m (6 ft) below groundlevel. During spring and for short periods after irrigation, water table levels may temporarily rise above the 2 m guideline.

3. Specific Ions

Chloride - use salinity guidelines

Sodium - use salinity and SAR guidelines

Boron - B less than 1.0 mg/L acceptable

B greater than 1.0 mg/L site specific evaluation
required for long-term use

4. Metals

The recommended maximum concentrations of trace metals in irrigation waters to be used on Saskatchewan soils are equivalent to those adapted by Environment Canada, 1984 and Westcot and Ayers, 1984; viz:

<u>Element</u>	<u>For waters used continually on all soil (mg/L)</u>	<u>For use up to 20 yrs on fine-textured soils of pH 6.0 to 8.5 (mg/L)</u>
Al	5.0	20.0
As	0.10	2.0
Be	0.10	0.50
Cd	0.010	0.050
Co	0.050	5.0
Cr	0.10	1.0
Cu	0.20	5.0
F	1.0	15.0
Fe	5.0	20.0
Li	2.5	2.6
Mn	0.20	10.0

Mo	0.010	0.050
Ni	0.20	2.0
Se	0.020	0.020
Sn	-	-
Ti	-	-
W	-	-
V	0.1	-
Zn	2.0	10.0

5. Nutrients

Major nutrients required by crops are nitrogen, phosphorus, and potassium. For Saskatchewan, it is recommended that nitrogen and phosphorus loadings from irrigation water (primarily wastewater) should match the crop requirements. For nutrient rich waters (i.e. secondary effluents) fertilization planning should be done in conjunction with soil testing.

6. Pesticides

Pesticides of concern in irrigation water include insecticides, herbicides, and fungicides. They include a large number of chemical compounds and they vary in their persistence in the environment. It is not expected that normal use of these compounds in Saskatchewan will cause problems with use of irrigation waters.

In Saskatchewan, there are no pesticide guidelines for tolerable concentrations in irrigation waters.

7. Organic Contaminants

Organic contaminants detected in low concentrations in wastewaters most frequently include the volatile organics such as

chloroform and benzene, polynuclear aromatics, chlorophenols, and phthalates. With the exception of polychlorinated biphenyls (PCB's) little is known about the "critical" concentrations and fate of toxic organics in treated wastewater. Although there is no evidence at present of adverse human health effects, continued vigilance is warranted.

8. Pathogenic Organisms

Pathogenic organisms are classified as bacteria, viruses, helminths and protozoa. The concern for pathogens has come about primarily through the use of wastewaters for irrigation. There is no evidence of disease outbreaks with irrigation of secondary or treated effluents, but outbreaks have been recorded where raw sewage has been used.

Fecal coliforms are considered a reliable indicator of effluent bacterial quality. To ensure elimination of fecal coliforms on field crops, effluent-irrigated crops should be exposed to a minimum of 10 hours of sunlight or 2 days of overcast but dry weather between the end of irrigation and the start of harvest.

Corn is unsuitable for spray irrigation of wastewater because of bacterial survival and reproduction within the husks and leaf sheaths.

Vegetable or market garden crops directly consumed by humans should not be irrigated with wastewaters; the exception being the use of gravity flood or furrow irrigation systems on certain crops.

9. Radionuclides

Radionuclides are generally not considered a problem but they could be a potential problem in some wastewater situations. If present in irrigation water, radionuclides tend to accumulate in the soil and result in subsequent plant bioaccumulation. A level harmful to humans could be reached before any plant damage is noted.

Until more is known, the recommended limits for radionuclides in irrigation water are patterned after the limits for drinking water. For Saskatchewan total alpha-radiation should not exceed 18.5 mBq/L (0.5 pCi/L) and total beta-radiation should not exceed 185 mBq/L (5 pCi/L).

D. RESEARCH NEEDS AND OTHER CONCERNS

During the compilation of this report it became apparent that there were several areas where it was felt that more research would be useful. Some of these areas are listed below:

1. There is a need for data on the effects of salts on yield reductions of commonly irrigated crops in Western Canada under our climatic conditions. It is felt that the California data on crop response does not always reflect the response of local varieties under Canadian climatic conditions.
2. The long term effect of irrigation waters in the soil exchangeable sodium percentage (ESP) and the counterbalancing effect of ESP-EC on soil structure and tilth is not entirely understood. Structural damage caused by excess sodium becomes expensive, difficult and time consuming to restore. Thus, for given soil types (textures) and climatic conditions, a better understanding of the long-term effects of the interaction of SAR, EC, and bicarbonates on the soil ESP is warranted. This would enable more precise critical limits to be set. Tilth is not entirely understood. Structural damage caused by excess sodium becomes expensive, difficult and time consuming to restore. Thus, for given soil types (textures) and climatic conditions, a better handle on long-term effects of the interaction of SAR, EC, and bicarbonates on the soil ESP is warranted. This would

enable more precise critical limits to be set.

3. Data from California indicate that plants have different tolerances to boron. Of importance to Saskatchewan, is that wheat and barley are apparently not very B tolerant, whereas oats and alfalfa can tolerate higher B concentrations. There is some concern about the reproductibility of the original experimental data on B, and further, there is concern that short term experiments where B adsorption takes place may underestimate the long term equilibrium B concentration. Although B is generally not a problem in Saskatchewan, some groundwaters and wastewaters are B enriched.
4. With the increased demand for use of agricultural lands to dispose of wastewaters and the general demand for the use of poorer quality waters where good water is scarce, a strong basis and philosophical framework for setting guidelines must be developed. For example, for long term use of such waters on agricultural land, is our overall philosophy to protect the land so that there will not be a net accumulation of salts or other harmful elements from irrigation; or can we afford some deterioration, particularly if increased productivity takes place? As an example, if irrigation of a particular tract of land might result in salinization of 10 to 20% of the land, but increase productivity by 2-3X on the remainder, then should the project in question proceed? What about potential salinization of off-target adjacent non-irrigated areas? As an extreme, should certain tracts of

agricultural lands be written-off as disposal areas for wastewater via irrigation or other means?

5. The concept of "drainability" and the use of water table levels as an indicator of drainability should be explored further. Because drainage can be controlled to some extent by man (tile drainage, rate of application), the concept becomes almost a site-specific factor to be considered.
6. Irrigation of problem soils has not been addressed in this paper, but may warrant further investigation. In one sense, these become site specific situations which may require individual consideration. Such problem soils include:
 - (a) Tough Solonetzic soils such as some of the Trossachs map complexes with numerous "burn-outs" which can present drainability problems related to very low permeability conditions. Irrigation of these soils may be aided by the use of amendments (gypsum) and physical rupturing of the B horizon (deep plowing, subsoiling).
 - (b) Saline soils can be reclaimed by irrigation with salty waters (from groundwater) provided adequate internal drainage is assured (i.e. a positive leaching fraction).
 - (c) Mine spoil reclamation may require the use of irrigation waters of designated quality to establish vegetation.
 - (d) Brine spill areas are generally small and confined. Enhanced leaching and recovery techniques by irrigation are being proposed as a reclamation technique for these soils.

E. REFERENCES

Cameron, D. R. 1985. Water quality soil compatibility guidelines for irrigation. Draft Technical Report prepared for Irrigation Branch, Sask. Agric.

Note: The above report is presently under review and revision by the Saskatchewan Irrigation Guidelines Committee. Copies with complete references are available from Irrigation Branch, Outlook, Saskatchewan.

PROBLEM WATER UTILIZATION IN RELATION TO SOIL SALINITY

J.L. Henry
Department of Soil Science
University of Saskatchewan
Saskatoon, Sask.

1. Introduction

The purpose of this paper is to communicate findings of research work conducted on soil salinity in Saskatchewan over the past 4 years. The research has uncovered potential groundwater resources that were previously unknown or whose extent and quality were unknown. The paper is intended more to stimulate new thinking on the relationships between soil salinity and aquifers rather than suggest immediate changes of direction.

2. Soil Salinity

The presence of soluble salts at the soil surface is a measure of the net water flux at the soil surface and in the plant root zone. Where the quantity of water leaving the soil surface through evaporation and transpiration is greater than the quantity of water entering and moving through the soil from rainfall or irrigation, then soil salinization is the inevitable result.

This means that soil salinization is a potential problem in any area of the world where evaporation exceeds precipitation for significant periods of the year. If the requirement of evaporation greater than precipitation were the only requirement then all arid areas would become saline. The second requirement is a source of water. The source of water is always a high water table but discovering the reason for the high water table leads us to the fundamental cause of soil salinization.

A high water table in itself does not result in soil salinization. In many humid areas of the world where rainfall greatly exceeds precipitation there is frequently a high water table, but no evidence of soil salinization. In these cases the net movement is downward and the soils are frequently highly leached and free of salts.

Thus, we see that a problem we refer to most frequently as soil salinity is really not a soil problem per se but would be more correctly termed a water problem.

3. Methods of Study

The Saskatchewan Institute of Pedology has, for the past 4 years, conducted field investigations and hydrogeologic studies to determine the cause of soil salinization throughout almost all agriculturally settled areas of Saskatchewan. The areas investigated have included Shaunavon, Ponteix, Assiniboia, Weyburn, Fort Qu'Appelle, Melville, Yorkton, Kamsack, Melfort, Annaheim, Prud'homme, Blaine Lake, Leask, Borden, Radisson, Langham, Dinsmore, Beechy, Kyle, Francis, Cut Knife, Wilkie and Sheho.

The first phase of the study includes examination of existing soil and hydrogeologic information in the form of soil maps, geology and groundwater maps, miscellaneous reports and water well files from both the Saskatchewan Water Corporation and the Saskatchewan Archives.

Field investigations include field surveys with non-contacting terrain conductivity (EM) meters and shallow auger drilling for stratigraphic information. A mobile field laboratory provides necessary analysis within hours of sample procurement. Of particular importance is salt analysis by electrical conductivity of both soil extracts and water samples.

In selected areas deeper investigations have been required and this information has been obtained by hydraulic rotary drilling using water well contractors. The drilling includes procurement of cutting samples at five foot intervals and electric (E) logging. The E-log is a most important segment of these investigations.

An interdisciplinary approach to the problem has been implemented and the disciplines of hydrology and geology have been a major input to the studies. These inputs have been effected through contract service with private consultants in these fields.

4. Results of These Studies and Examples of Aquifers Encountered

As a summary statement it has been found that the vast majority of salinized soil in Saskatchewan has been salinized as a result of groundwater discharge from both glacial and bedrock aquifers under artesian pressure. What follows is a summary statement about these aquifers and their characteristics.

4.1 Valley aquifers

In terms of potential groundwater for irrigation purposes the preglacial valley aquifers have most often been considered. A first approximation to the location and extent of these aquifers was obtained by the Saskatchewan Research Council in the geology and groundwater investigation program of the 1960's and 1970's. These have all been published in the form of NTS map sheets at a scale of 1:250,000.

The major preglacial valley is the Hatfield Valley which has recently been studied by Maathuis and Schreiner (1982). This aquifer is a major cause of soil salinization in portions of the Quill Lakes-Last Mountain Lake Basin. Other valley aquifers of note include the Tyner Valley in central Saskatchewan and the Swift Current and Estevan Valleys in the southern regions.

Both the Hatfield and Tyner valleys are currently being used for irrigation purposes. The salt content of the water is approximately 3,000 mS/cm. The long term implications of utilization of this water are unknown.

As a consequence of soil salinity studies in the Radisson-Borden area we have obtained additional information on the Battleford Valley. Figure 1 shows an example of an electric log in the Battleford Valley north of Radisson. The aquifer at this location is very well developed and would be capable of delivering large quantities of water. Farm wells and piezometers suggest a water quality of approximately 1,500 mS/cm. In the areas we have studied the piezometric surface of the Battleford Valley is well below soil surface and we do not know of any location where the Battleford Valley is responsible for soil salinization. In the areas we studied the salinization was due to artesian pressure from

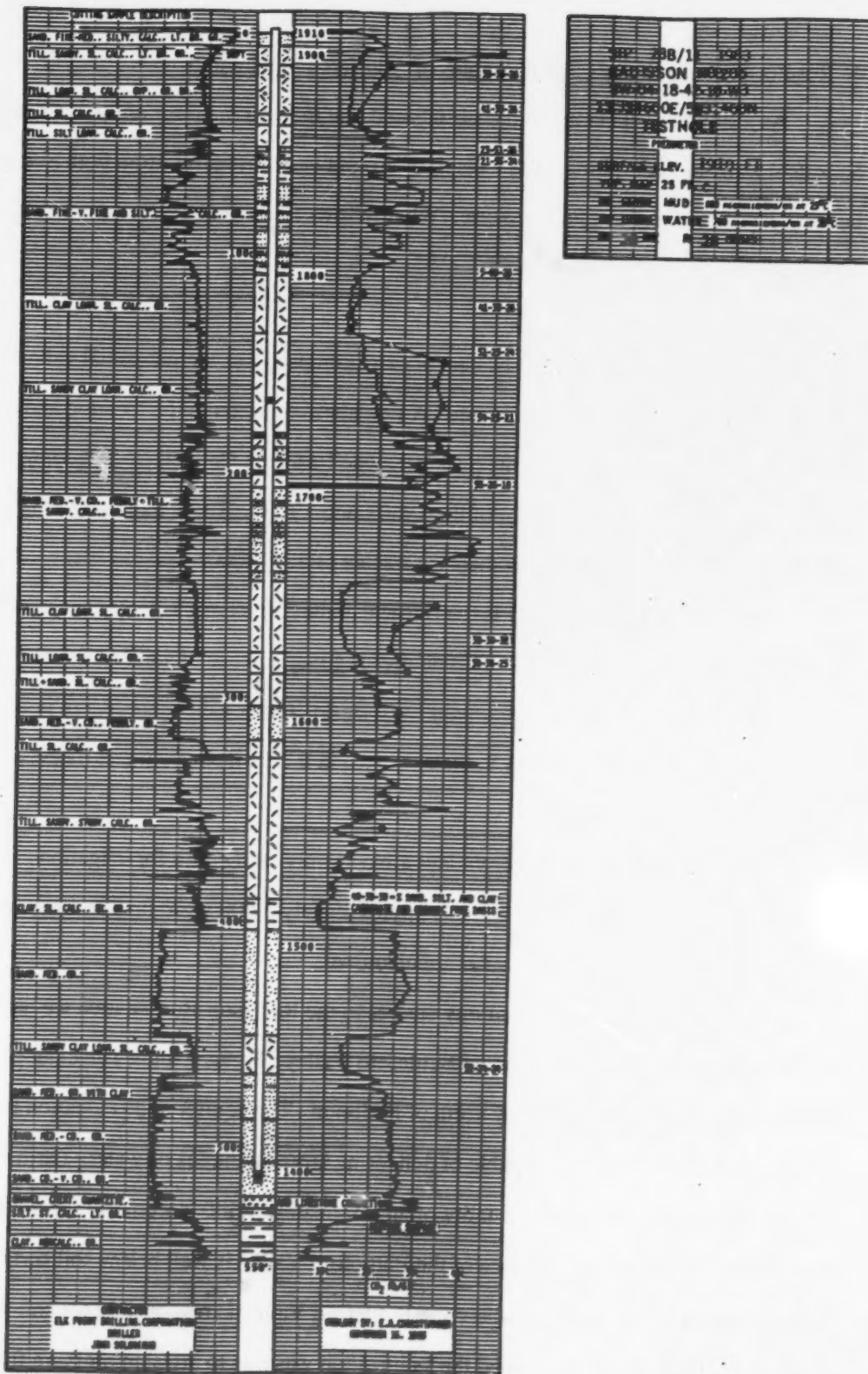


Figure 1. E-log and geologic log of a testhole in the Battleford valley.

intertill aquifers above the Battleford Valley and the information we obtained about the Battleford Valley was a "spin-off" result of the studies.

4.2 Bedrock aquifers

The Judith River formation is perhaps the most significant bedrock aquifer in Saskatchewan and in a number of situations is responsible for soil salinization. The stratigraphy of the Judith River formation has been extensively studied (McLean, 1971) and a recent assessment of its potential as an aquifer has been published (Whitaker, 1985). With the current drought conditions in southwest Saskatchewan there have been numerous Judith River farm wells completed in the past two or three years. Much of the Judith River formation contains water with conductivity values exceeding 3,000 mS/cm with SAR values of 40 or greater. This, coupled with the usual low yields of the Judith River formation, mean that it deserves no further consideration in terms of utilization for irrigation or for disposal on land in desalinization attempts.

Sand members of the Bearpaw formation are responsible for soil salinization in some areas but they have the same limitations in quality and quantity as does the Judith River formation.

In southern Saskatchewan aquifers in sand members of the Eastend-Ravenscrag formations are a major occurrence. The geology and hydrology of these formations has recently been summarized (Meneley, 1983). In eastern Saskatchewan and central portions, the water in this aquifer is quite highly mineralized and sodic in nature with high chloride content as well.

The Shaunavon aquifer within this formation in the Shaunavon area offers perhaps the greatest possibilities in terms of water utilization and saline reclamation. We have studied the soil salinization by this aquifer in the area west of Shaunavon.

Hydrographs by the Saskatchewan Research Council are available for the Shaunavon area within the pumping influence of the Shaunavon well field (Shaunavon Observation Well) and outside of this field of influence (Garden Head Observation Well).

The Shaunavon observation well shows fluctuations in relation to precipitation cycles but the Garden Head observation well shows a steady increase in piezometric surface from the installation in the mid 1960's to about 1980 and a more or less static condition since that time.

If the piezometric head on such an aquifer increases over time then it is almost a certainty that more salinization will take place. Perhaps the possibility of utilizing some of this water should be investigated, although the extreme importance of this aquifer for farm and urban use cannot be overemphasized.

The Shaunavon aquifer does discharge into the upper reaches of Notukeu Creek and in dry cycles much of the water present in Cadillac reservoir is probably discharged from this aquifer. Perhaps the possibility of using wells to assist this discharge process into Notukeu Creek should be examined.

4.3 Glacial aquifers

Glacial stratigraphy in Saskatchewan has been described previously (Christiansen, 1968). In our work we have discovered aquifers in the Floral formation of the Saskatoon group and in the Sutherland group which are responsible for soil salinization. The most frequent occurrence and the aquifers with the greatest potential for utilization in irrigation-desalinization programs are those in the Floral formation. These aquifers include the Dalmeny, Blaine Lake, Fielding, Tessier, Phippen and Regina aquifers. Water quality in most of these intertill aquifers ranges from 1,500 to 3,000 mS/cm with the greatest quantity of the water having a conductivity of approximately 2,000 mS/cm. The exceptions to this are the Fielding aquifer in the Radisson-Fielding-Maymont area and the Phippen aquifer in the Wilkie area. Almost all conductivity measurements in these aquifers are less than 1,000 mS/cm. In the Fielding aquifer most wells have a conductivity value of approximately 600 mS/cm which is about the same quality as the North Saskatchewan River.

The Fielding aquifer is particularly well developed in the area west and north of Radisson. Figure 2 shows an electric log of a testhole we completed in the Fielding aquifer

PIEZOMETER

SURFACE ELEV. 1740 FT.

TOP MARK 25 FT

SP COND	MUD	1125 MICROS/CM AT 25°C
---------	-----	------------------------

SE COND WATER 700 MICRONS/CM AT 25°C

SW 1/4 NW 1/4

CUTTING SAMPLE DESCRIPTION

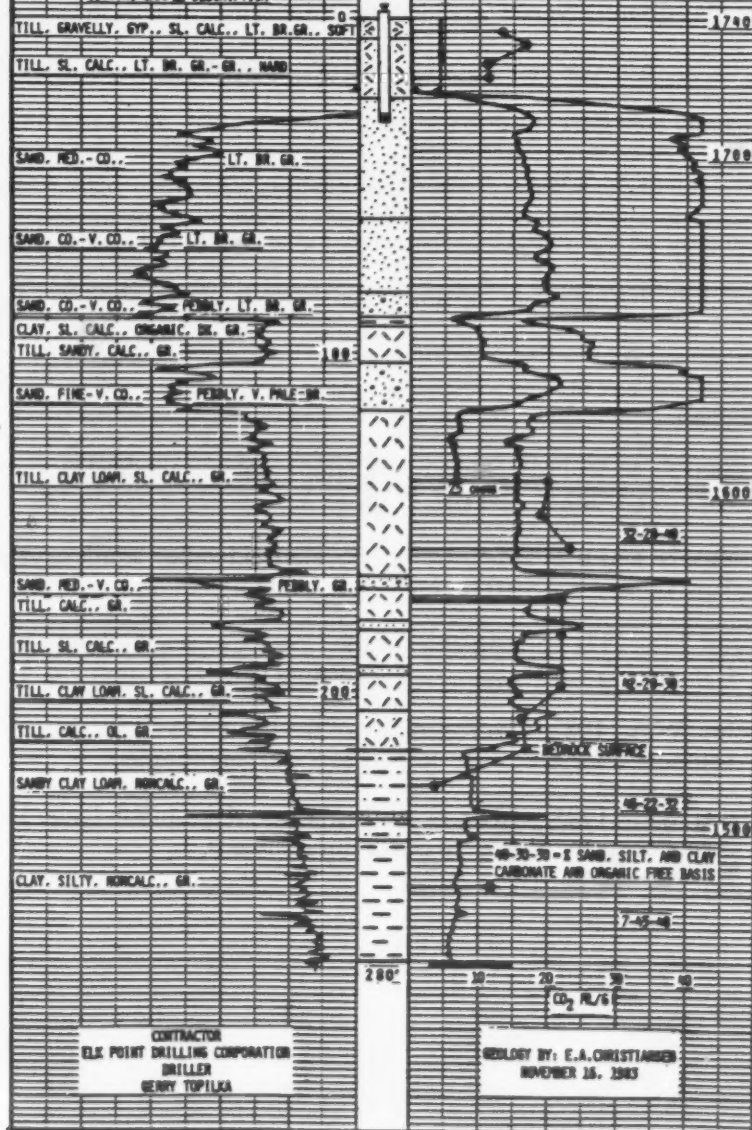


Figure 2. E-log and geologic log of a testhole in the Fielding aquifer.

in that area. Piezometric surface is just above ground surface throughout the salt-affected area west of Radisson. Limited information from pumping associated with one irrigation project in the area has suggested that annual yield in the Fielding aquifer may be approximately 2,000 acre feet.

5. Summary and Conclusions

In summary, it can be stated that salinization of soils in Saskatchewan is caused in large measure by discharge from glacial or bedrock aquifers. Where the aquifers are sufficiently well developed to provide large well yields and where the water quality is suitable it may be feasible to utilize sufficient water in an irrigation sense to lower the piezometric surface enough to affect the drainage required for desalinization. The greatest potential for this approach appears to take place in glacial aquifers of the Floral formation.

References

- Christiansen, E.A. 1968. Pleistocene stratigraphy of the Saskatoon area, Saskatchewan. *Can. J. Earth Sci.* 5: 1167-1173.
- Maathius, H. and B.T. Schreiner. 1982. Hatfield valley aquifer system in the (Melville, Wynyard, Waterhen) regions. S.R.C. Publication.
- McLean, J.R. 1971. Stratigraphy of the Upper Cretaceous Judith River formation in the Canadian Great Plains. *Sask. Research Council Report No. 11.*
- Meneley, W.A. 1983. Hydrogeology of the Eastend to Ravenscrag Formations in southern Saskatchewan. Report to Sask. Environment.
- Whitaker, S.H. 1985. Groundwater resources of the Judith River Formation in southern Saskatchewan. Report to Sask. Environment.

Irrigation Suitability Classification System for the Prairies

R.G. Eilers

ABSTRACT

Guidelines for evaluating the suitability of land for irrigation are presently under revision by an interprovincial working group. The revised guidelines emphasize the physical and morphological properties of soil and landscape which affect the intake, retention, and transmission of water through the profile. Factors affecting soil quality are also considered. The new system for evaluating irrigation suitability utilizes the concept of limiting factors. The kind and degree of limitation (none, slight, moderate, or severe) for each relevant soil and landscape property is determined from standard look-up tables. The degree of limitations for soil and landscape features are then combined in a matrix. The irrigation suitability rating of excellent, good, fair, or poor is determined by the most limiting factor.

The proposed system for classifying irrigation suitability pertains specifically to land. Assessing the suitability of the land base is considered to be the first priority for irrigation evaluation. The system does not incorporate the numerous other factors such as climate, agronomy, water availability, markets, economics, etc. that influence the decision of whether or not to irrigate.

¹ Canada-Manitoba Soil Survey, University of Manitoba, Winnipeg

AN IRRIGATION SUITABILITY CLASSIFICATION SYSTEM
FOR THE CANADIAN PRAIRIES*

R.G. EILERS

ACKNOWLEDGEMENTS

To begin, I would like to acknowledge that the proposed system dealt with in this report, is the direct result of the activities of an inter-provincial working group on Irrigation Suitability Classification. I would like to extend sincere appreciation to each of the members of the working group and to the numerous other people who have provided reviews and constructive suggestions in the development of this system.

INTRODUCTION

Irrigation has been a method of farming on the prairies since the early 1890's (1). Until 1935 most of the irrigation was under small scale private development. However, in 1935 the Prairie Farm Rehabilitation Administration (PFRA) was established to provide government assistance to both irrigation and dry land farming. As larger scale irrigation districts were established the need to evaluate the quality and suitability of land for irrigation became a prime requirement. The first handbook for irrigation suitability classification for the prairies was published in 1964 by PFRA (2). This handbook dealt primarily with criteria and land development costs related to flood-type irrigation. Over time, each province adopted and modified the system for local application, and as a result a gradual divergence in methodology developed between provinces.

In 1981 an interprovincial working group was established to review the existing criteria and to develop standardized guidelines and procedures for evaluating irrigation suitability which would have broad application to all of the prairies. This paper describes the essential points of a proposal for a revised system which has been developed to meet the regional and local needs of various agencies concerned with irrigation development (3). The proposed system is currently under review and is available for test application and evaluation.

* Paper presented to Fourth Annual Western Provincial Conference, Rationalization of Water and Soil Research and Management, Saskatoon, Saskatchewan, November 25-27, 1985.

A REVISED IRRIGATION SUITABILITY CLASSIFICATION (ISC) SYSTEM

The major considerations addressed by the working group during the revision of the I.S.C. system are as follows:

1. A standardized ISC system should utilize soil survey data or data that can be obtained through standard soil survey investigations. Soil survey procedures are well established and documented (4, 5, 6). Thus, there is no need to develop another field survey technique to evaluate irrigation suitability. Provincial soil survey programs can provide soil and landscape information appropriate for interpreting irrigation suitability. Unfortunately, detailed soil information is available for only a small part of the prairies where irrigation demands are highest. However, on a broad scale, reconnaissance soil maps and reports can provide information for a general overview of irrigation suitability.
2. The ISC system should be interpretive and independent of map scale. This would provide flexibility and facilitate its application to various levels of soil information and map scales that presently exist across the prairies.
3. The ISC rating should be determined by the most limiting factor. The utilization of the limiting factor concept emphasizes the kind and seriousness of the problem interfering with proposed irrigated land use. The kind of limitation may relate to internal soil conditions of the profile or external soil conditions of the landscape. The degree of limitation is given a relative ranking according to none, slight, moderate, and severe.
4. The ISC system should indicate the suitability class as well as the kind of limitation with connotative symbols. Connotative symbology would facilitate use and understanding of the map and would immediately highlight the nature of the limitation.
5. The ISC system should be designed to be compatible with automated data processing techniques. Numerous algorithms have been developed to do land evaluations. Therefore, the adoption of standardized class limits for soil and landscape properties as currently utilized in soil surveys would facilitate the automation of land evaluation for irrigation suitability.
6. The ISC system should be independent of water application techniques. Technology has made it economically feasible to design

tailor-made irrigation systems to fit the land conditions or alternatively, to modify the land conditions to fit the irrigation system. Therefore, the proposed system is not concerned with methods of water application.

7. The ISC system should identify relative suitabilities rather than irrigability or productivity. Suitability is rated as excellent, good, fair, or poor based on the degree of limitation. A poor suitability rating is not synonymous with non-irrigable, although in many instances there will be a close relationship. The final decision as to irrigability, will consider the method of water application, type of crops to be grown and an economic analysis of cost:benefit ratios to determine profitability.

DATA REQUIREMENTS

The proposed ISC system utilizes both soil and landscape data to designate a final suitability rating. Soil information pertains to the internal physical, chemical and morphological properties identified from soil profiles and bore holes. Landscape properties, on the other hand, refer to characteristics of the soil surface.

The major factors affecting the irrigation suitability of soils are those which affect the intake, retention and transmission of water through the soil profile. A comprehensive list of soil and landscape features affecting irrigation is given in Tables 1 and 2, respectively. An example of how the criteria for each parameter is defined utilizing standard class limits and arranged according to the relative degree of limitation for irrigation suitability is shown in Table 3. The following list identifies some of the soil characteristics desirable for irrigation. Significant deviation from these requirements will be considered as a type of limitation.

1. Sufficient water holding capacity to ensure efficient utilization of applied water.
2. Good internal soil drainage to provide proper aeration of the root zone and permit leaching of soluble salts.
3. Sufficient infiltration rates to minimize the potential for erosion and to replenish moisture lost through evapotranspiration.
4. Sufficient depth of suitable soil material to facilitate root development and provide adequate storage of moisture and plant nutrients.
5. Suitable texture, structure and consistency to permit necessary and timely field operations.
6. Lack of injurious amounts of salinity, sodicity or toxic elements.

USE AND INTERPRETATION OF THE GUIDE TABLES

It is intended that each property (Tables 1 and 2) be evaluated on its own merits in terms of its expected performance under irrigation, or in terms of its degree of limitation for irrigation. Although many of the soil features are closely related, they are retained as separate items in the table to ensure their consideration in any irrigation suitability evaluation. The comprehensive nature of Table 3 will facilitate ISC interpretation utilizing various levels of available soil and landscape data.

DETERMINING THE IRRIGATION SUITABILITY OF LAND

The procedure for rating the irrigation suitability of land utilizes the limitations for both soils and landscape as combined in Table 4. Four ratings of suitability, defined according to excellent, good, fair, or poor, are determined by the most limiting factor as defined in Table 3. A general description of the individual irrigation land classes is given in Table 5 and the irrigation suitability ratings are defined in Table 6.

SYMBOLOLOGY FOR INDICATING IRRIGATION SUITABILITY

The proposed symbology for designating the irrigation suitability of land combines the limitation for soil with the limitation for landscape as shown in Table 4. Specific limitations as defined in Tables 1 and 2 are also indicated by adding the unique symbols to the soil-landscape rating. A maximum of three specific limitations may be utilized if necessary with preference given to the major limiting factor(s).

e.g.

 Soil Limitation
Landscape Limitation
2 A x—Specific Limitation(s) (1 to 3)

An example of an ISC rating could be:

3B swp indicates a unit with fair suitability for irrigation

This land unit has moderate soil limitations but only slight landscape limitations. The specific soil limitations are identified as salinity (s) and wetness (w) whereas the landscape limitation is identified as stoniness (p).

SUMMARY

In summary, the proposed ISC system is perceived to have the following advantages:

1. Soil and landscape features which affect the suitability of land for irrigation are identified.
2. The degree of limitation for each property of soil and landscape is clearly indicated.
3. The symbology used to indicate limitations is unique and connotative to facilitate use and understanding of the suitability rating.
4. The system has flexibility to be useful at various map scales and levels of soil information.
5. The system utilizes only soil and land resource information; thus, its application is not limited to any specific geographic location.
6. The system is not limited to any particular technology of water application.

REFERENCES

1. History of Irrigation in Western Canada (1982). Prepared by Prairie Farm Rehabilitation Administration.
2. Handbook for the Classification of Irrigated Land in the Prairie Provinces - PFRA, Regina, 1964.
3. An Irrigation Suitability Classification System for the Canadian Prairies - Draft Report of the Working Group on Irrigation Suitability Classification - April, 1985.
4. Manual for Describing Soils in the Field, 1978, Revised. The Canada Soil Information System, Land Resource Research Inst., Central Experimental Farm, Ottawa, Ontario K1A 0C6. 92 pp.
5. Canada Soil Survey Committee, Subcommittee on Soil Classification. 1978. The Canadian System of Soil Classification. Can. Dep. Agric. Publ. 1646, Supply and Services Canada, Ottawa, Ont. 164 pp.
6. A Soil Mapping System for Canada: Revised 1981. Prepared by Mapping System Working Group of the Expert Committee on Soil Survey. Land Resource Research Inst., Contribution No. 142, Research Br., Agriculture Canada.

Table 1. Soil Features Affecting Irrigation Suitability

<u>Soil Feature</u>	<u>Symbol</u>	<u>Remarks</u>
Texture	-	Not considered to be a limitation by itself. Texture infers other characteristics which may limit suitability for irrigation.
Structure	-d-	May pose slight to moderate limitation.
Available Water	-m-	Measured in mm to depth of 1.2 m.
Holding Capacity		May be inferred from texture.
Saturated Hydraulic Conductivity	-k-	Measured in mm/hr indicates rate at which water may be removed from the soil profile.
Geological Uniformity	-g-	Described to a depth of 3 m.
Depth to Bedrock	-r-	Not a limitation if >3 m.
Intake Rate	-q-	Measured in mm/hr - indicates minimum rate for water to enter the soil.
Drainage Class	-w-	Indicates moisture status of profile.
Depth to Water Table	-h-	Measured in meters - not considered to be a limitation if greater than 2 m (saturated soil zone).
Organic Matter (%)	-	Not considered to be a limitation to irrigation - but may affect other important soil properties.
Salinity	-s-	Measure of salt content in and below the root zone.
Sodicity	-n-	Indication of soil quality related to the chemistry of the soluble salts - measured by determining sodium-absorption ratio (SAR).

Table 2. Landscape Features Affecting Irrigation Suitability

<u>Landscape Feature</u>	<u>Symbol</u>	<u>Remarks</u>
Slope	-t-	Identified by classes - may be simple or complex
Average Local Relief	-e-	Measure in meters of elevation from crest of knoll to bottom of depression, used mainly in areas with complex slopes
Stoniness	-p-	Stoniness classes indicate % of ground cover
Flooding Frequency	-i-	Number of occurrences in a given time period
Potential Impact on Non-Target, Non-Irrigated Areas	-c-	Relative ratings from none to high
Horizontal Variability of Infiltration	-v-	Relative rating from very low to high

Table 3. An Example of How Criteria for Soil and Landscape Features Will Be Arranged According to Classes and Ranked for Degree of Limitation for Irrigation

a) Soil Features Affecting Irrigation Suitability

Symbol	Soil Feature	Degree of Limitation			
		1 None	2 Slight	3 Moderate	4 Severe
m	A.W.H.C. (mm/1.2m)	> 120	120-60	60-30	< 30
r	Depth to (m) Bedrock	> 3	3-2	2-1	< 1
s	(m) Salinity 0-.6 (dS/m) .6-1.2 1.2-3	< 2 < 4 < 8	2-4 4-8 8-16	4-8 8-16 16	> 8 > 16
etc.					

b) Landscape Features Affecting Irrigation Suitability

Symbol	Landscape Features	Degree of Limitation			
		A None	B Slight	C Moderate	D Severe
t1	Slope (%) (simple)	< 2	2-10	10-20	> 20
t2	(complex)	-	< 5	5-15	> 15
etc.					

NOTE: To define degree of limitation, the indicated class limits usually represent minimum conditions.

TABLE 4.

Soil-Landscape Relations Determining Irrigation Suitability

SOIL LIMITATIONS LANDSCAPE LIMITATIONS	IRRIGATION SUITABILITY RATING			
	NONE	SLIGHT	MODERATE	SEVERE
1				
A	1A	2A	3A	4A
	1B	2B	3B	4B
	1C	2C	3C	4C
D	1D	2D	3D	4D

IRRIGATION SUITABILITY RATING



Table 5. Definition of Individual Irrigation Land Classes

<u>Land Class</u>	<u>General Description</u>
<u>Irrigation Suitability Rating - Excellent</u>	
1A	Lands have no internal or external features which limit or restrict their use for irrigation
<u>Irrigation Suitability Rating - Good</u>	
2A	Lands have slight limitations for irrigation due to unfavorable soil characteristics
1B	Lands have slight limitations for irrigation due to unfavorable landscape characteristics
2B	Lands have slight limitations for irrigation due to a combination of both soil and landscape characteristics
<u>Irrigation Suitability Rating - Fair</u>	
3A	Lands have moderate limitations for irrigation due to adverse soil characteristics
3B	Lands have moderate limitations for irrigation due to adverse soil characteristics and a slight limitation due to unfavorable landscape characteristics
3C	Lands have moderate limitations for irrigation due to a combination of adverse soil and landscape characteristics
1C	Lands have moderate limitations for irrigation due to adverse landscape characteristics
2C	Lands have moderate limitations for irrigation due to adverse landscape characteristics and slight limitations due to unfavorable soil characteristics
<u>Irrigation Suitability Rating - Poor</u>	
4A	Lands have severe limitations for irrigation due to deficient internal soil characteristics
4B	Lands are poor for irrigation due to severe limitations of internal soil conditions and slight limitations due to landscape characteristics
4C	Lands are poor for irrigation because of severe internal soil limitations and moderate landscape limitations
4D	Lands are poor for irrigation because of severe soil and landscape limitations
1D	Lands are poor for irrigation because of severe landscape limitations
2D	Lands are poor for irrigation because of severe landscape limitations and slight soil limitations
3D	Lands are poor for irrigation due to severe landscape limitations and moderate soil limitations

Table 6. General Descriptions of Irrigation Land Classes

Irrigation Land Classes	Suitability Rating	Description
1A	Excellent	Lands in this class have no significant limitation(s) for irrigation. Lands in this class are capable of producing a sustained and relatively high yield of a wide range of climatically adapted crops. The soils are medium textured, well drained, and hold adequate available moisture. Harmful accumulations of soluble salts are absent from the soil and topography is level to nearly level. These lands are generally considered to be excellent for irrigation.
2A 2B 1B	Good	Lands in these classes have slight limitations for irrigation due to unfavorable characteristics of either the soil or landscape or both. A narrower range of crops or slightly more input to development and management may be required. They can be maintained or possibly improved with proper management. The soils in these classes may be heavier or lighter in texture than soils in Class 1A. The specific factor(s) limiting irrigation use of these lands is designated by connotative lower case symbol(s) following the land class symbols.
3A 3B 3C 1C 2C	Fair	Lands in these classes have moderate limitations for irrigation use due to deficient characteristics of either the soil, the landscape or a combination of both. The soils may be inferior because of excess salinity, sodicity, very low hydraulic conductivity or low water holding capacity. The specific factor(s) limiting irrigation utilization of these lands will be designated by connotative lower case symbol(s) following the land class symbols. Greater management input as well as more intensive soil conservation and improvement practices are required for this group of soils than for the soils in the good category.
4A 4B 4C 4D 1D 2D 3D	Poor	Lands in these classes have severe limitations for irrigation use due to adverse characteristics related to either the soil, the landscape or a combination of both. These lands may have some limited use under irrigation but generally their limitations are so severe that they do not form suitable irrigation-farm units. Special crops, irrigation system designs, and special soil and water management practices will be required to irrigate any lands in this category.

APPLICATION OF SOILS INFORMATION TO IRRIGATION PLANNING AND MANAGEMENT

by

L. A. Loskiw

This paper addresses the use of conventional soil surveys and land irrigability classification systems used in planning, developing and managing irrigated lands in Alberta. While many of the details are provincial in scope, the general principles, as outlined below and discussed in the text, are definitely applicable across the prairies.

Currently, land irrigability evaluations by soils specialists systematically provide information revealing:

- location and extent of irrigable soils,
- rating of land suitability for sprinkler and gravity irrigation, and
- soil physical and chemical properties.

In addition, measurements or inferences are or may be made regarding:

- the need for canal lining,
- drainability of soils,
- soil-water relationships,
- soil fertility, and
- crop productivity.

But a much better data base is urgently needed. Examples of interpretations that should be provided include:

- guidelines for reclaiming salt-affected lands,
- recommended water application: amounts and frequencies to optimize yields and maintain low salt levels,
- soil fertility management,
- soil erosion control practices, and
- economics: inputs and returns, on-farm and off-farm.

To achieve high and economic crop yields -- the soil-water-plant system must be understood and managed intensively at the farm level. However, in order for this "system" to work efficiently at the farm level, these relationships must also be recognized and taken into account at the planning stage through to the operational stage. It is clear that modifications to our present land mapping and suitability rating approaches are needed in order to provide necessary inputs to all these stages. Furthermore, an integrated approach involving planners, engineers, agronomists, soil scientists and economists is essential to developing/operating highly successful irrigation schemes.

¹ Principal of Pedology Consultants

INTRODUCTION

This paper focusses on the land component of irrigation development in Alberta. Procedures used in classifying irrigable lands are summarized, some positive aspects of the approach are noted and key concerns arising from serious and growing problems in the irrigation sector are highlighted. Implications of these are relevant across Western Canada.

It is clearly evident that many of the concerns can only be addressed properly in an integrated, multi-disciplinary manner. This means producers, government agencies, agri-businesses and consultants representing a cross-section of disciplines must work together.

REVIEW AND DISCUSSION

The Role of Soils

The main objective of agricultural development should be to bring about optimal utilization of the natural resources of the area for food production. In this sense optimal utilization means the achievement of the most beneficial production without deterioration of the natural soil resource, in other words, sustained, efficient productivity.

Planning for optimal land use is not only a function of the natural physical and biological resources of an area, but it is also determined by the prevailing socio-economic and political conditions. Items to be considered include management abilities of farmers, integrating different types of agriculture (range complementing crop, rainfed complementing irrigated, etc.), technology of farm machinery available, the risk factor, transportation costs to local and foreign

markets, marketing opportunities, etc. It is recognized that in the short-term socio-economic and political variables may play a key role in the decision making process. However, in the long-term, it can be firmly stated that the nature of the land resources of an area form the physical ceiling beyond which present technology will not allow people to pursue objectives generated by the social and political aspirations. In western Canada, the soil resources form part of this physical ceiling.

Soil Surveys and Land Classification Systems in Alberta

In Alberta, reconnaissance soil surveys emphasizing topsoil texture and topography were first carried out in the 1920's in the South. Later, during the 1950's through 70's, reconnaissance mapping, emphasizing the upper metre of soil, was conducted on all the agricultural lands of Alberta (not all maps have been published to date but information is available in Alberta Soil Survey files). These surveys formed the basis for the Canada Land Inventory Soil Capability for Agriculture (Dryland) published at a scale of 1:250,000. The production of these soils and agricultural capability maps cost in the order of a few cents per acre surveyed: they have been very useful for broad, regional planning purposes, creating public awareness concerning the need to preserve prime farmlands and the need to practice soil conservation and so forth. In this regard they have been highly successful, however, at the farm management level they are too general to be useful.

Soil and dryland agriculture capability surveys are now being conducted at a semi-detailed level on a County/Municipal District basis and are to be published at a scale of 1:50,000. Since few of these have been completed to date it is difficult to judge their usefulness at the farm level. For regional planning, they will be greatly

superior to the older reconnaissance surveys. To be applicable for irrigation development planning, additional information below the upper metre of soil will be required.

Irrigation land classification was initiated during the 1930's based on a "Table of Ratings" compiled by the Irrigation Council of Alberta. During the 1950's and 60's, refinements to the classification criteria were made as reflected by publications by Bowser and Moss, 1950; and PFRA, 1960; progressing to the "Handbook for the Classification of Irrigated Land in the Prairie Provinces", PFRA, 1964. The latter outlined a system for classifying lands according to their earning potential, that is, projected future net income per acre based on soils characteristics, topography, drainage requirements, production inputs and crop yields. In my opinion, this was the best system ever used in Alberta in terms of regional planning needs as well as applicability at a farm level.

Subsequent irrigation classification systems developed by the Water Resources Division, in 1968, and revised by Alberta Agriculture, in 1983, followed and improved on the PFRA approach in terms of rating soils and topography but the integrating economics component has been dropped and the drainage component has been downplayed to the point of now being totally inadequate. While the current classification provides a systematic approach for rating lands suitable for irrigation based on present soil and topographic conditions, the lack of detailed analysis regarding drainage prevents one from positively predicting that irrigation can be permanent. However, before expanding on the need for more intensive investigation of drainage aspects, and other applications of soils information, a brief review of current irrigability classification procedures is given.

Two levels of irrigation land classification are now carried out as follows:

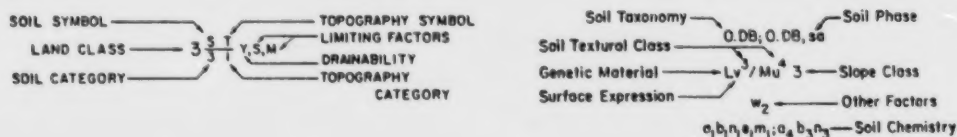
Level III (Medium Intensity)

- mapped at a scale of 1:20,000 and published at both 1:20,000 and 1:40,000,
- based on a minimum of four sampling sites to 2 metres, one to 4.5 m, plus eight inspections to 1 metre per section,
- conducted on blocks usually covering a few townships where lands appear to have potential for irrigation "based on land characteristics and possible water availability", and
- conducted for planning purposes only.

Level II (High Intensity)

- mapped and published at a scale of 1:5,000,
- based on a minimum of four sampling sites to 2 metres, one to 4.5 m, plus six inspections to 1 metre per quarter section,
- usually conducted on quarter-sections in response to farmers' requests, and
- conducted for the purposes of obtaining water rights and determining "acres to be irrigated".

Baseline information about the map units is presented in a very complex map symbol which is similar in both levels of surveys and includes:



The foregoing features are evaluated and rated for irrigation by components:

- soil categories: (1) excellent, (2) good, (3) fair, and (4) non-irrigable.
- topography categories: (1) gravity, (2) sprinkler, (3) special system design, and (4) non-irrigable.

- drainability: (x) moderately to rapidly permeable, (y) slowly permeable, (z) impermeable.
- limiting factors are also stated.

Finally a land class is assigned and it is based mainly on the soil and topography components. Land Classes 1 to 4 are irrigable with progressively greater limitations, Class 5 is non-irrigable but has potential to be improved or must be studied in more detail, and Class 6 is non-irrigable.

Uses of Irrigation Land Classification

The irrigability maps provide much information about the land resources of an area even though one has to be an expert to decipher the complex map symbols. Nevertheless, once a thorough understanding of the symboling is gained, the following irrigation related information is evident:

- distribution and ranking of irrigable soils,
- location of non-irrigable lands including wetlands,
- location of natural drainage courses, and
- suitability for gravity or sprinkler irrigation.

If not apparent on the mosaic base, overlays showing present land use, roads, irrigation and drainage canals, pipelines, powerlines, other man-made features, and contour lines can be superimposed to aid in development planning.

Other important information needed for irrigation planning can be inferred from the maps but this is not always done, nor are procedures for doing so standardized. Examples include:

- Canal lining requirements. This can be interpreted from soil permeability as expressed by the drainability factor, soil textures and depths.
- Irrigation management practices. Soil textures provide the basis for estimating average infiltration and hydraulic conductivity rates which are essential for determining irrigation application rates and frequencies as well as leaching and drainage requirements.
- Soil fertility. General inferences about soil nutrient status can be made based on texture, organic matter levels, profile depth and nutrient contents.
- Crop selection. Soil salinity levels broadly indicate whether crop production may be restricted to salt tolerant species. Similarly, preferred crops can be matched with soil textures and stoniness levels. Crop yield data for irrigated vs dryland conditions on specific soil types are rare, unfortunately.
- Soil erodibility. Soil textures and slopes can be interpreted to provide general guidelines regarding erosion hazard and the "eroded" soil phase indicates areas where serious erosion has occurred.

Of course, there are many other extensions of the soils base which could be extremely valuable, such as, dryland agricultural capability, farm assessment, wetland management, grazing capability, wildlife habitat suitability, recreation and other uses. These uses are not considered as part of irrigation land classification but some are or could be included in regular soil surveys.

Nevertheless, at the regional or "block" planning level the Level III surveys appear to provide a reasonable basis for planning irrigation projects. A major question and one of greatest concern is that of irrigation permanency especially with regard to salinity -- will soil productivity be sustained? This does not mean compensating for higher soil salinity by increasing fertilizer applications or shifting to only highly tolerant species to maintain yields. This means providing drainage where required, in addition to irrigation, maintaining salt levels in drainage outlets (streams, rivers) within acceptable levels, and growing crops that will provide a reasonable net return to the producer.

Soil Salinization

Since 1978 I have mapped about 1 million acres of irrigated and drylands within and outside existing Irrigation Districts in southern Alberta. In all areas surveyed I have encountered significant acreages of saline soils, some attributable to natural causes, others to dryland practices and many to irrigation. Extents and degrees of salinization vary considerably from one area to another depending on soils, parent materials, topography, groundwater levels, irrigation history, and so forth, but consistently irrigated lands tend to be more salinized than drylands.

This problem is recognized and Alberta Agriculture has conducted an inventory of saline and/or wetland areas within the Eastern and Western Irrigation Districts. Initial findings are alarming. Table 1 provides a listing of results published to date including Districts, percentages salinized at different levels and comments regarding sources of results. Note that salinity as mapped does not include solonetzic soils which are extensive in some localities. Some major difficulties arise in interpreting the results, however, because the surveyed areas are much greater than the irrigated areas and

Table 1. Estimated Percentages of Saline Lands in Different Classes by Irrigation District.

IRRIGATION DISTRICT	SALINITY CLASS ¹				COMMENTS
	3 Moderate	4 Saline	5 Highly Saline		
1. Mountain View	(6) ²	(2)	(2)		- approximate regional average (Sommerfeldt, et al., 1984)
2. Leavitt	(6)	(2)	(2)		- approximate regional average (Sommerfeldt, et al., 1984)
3. Aetna	(6)	(2)	(2)		- approximate regional average (Sommerfeldt, et al., 1984)
4. United	(6)	(2)	(2)		- approximate regional average (Sommerfeldt, et al., 1984)
5. Magrath	7	6	6		- based on interpretation of land classification by Vander Pluym and Kerr, 1971
6. Raymond	18	2	2		- based on interpretation of land classification by Regier (1972-73)
7. Lethbridge Northern	9	2	3		- based on interpretation of land classification by Regier (1972)
8. Taber	11	3	3		- based on detailed mapping of 30 quarters (Alberta Agriculture surveys)
9. St. Mary River	7	6	7		- based on grid surveys (Alberta Agriculture, Heywood and Mikelson, 1974,75)
10. Ross Creek	(5)	(5)	(5)		- guessed to be slightly less than SMRID
11. Bow River	(10)	(5)	(5)		- guessed to be slightly less than EID
12. Western	(10)	10	16		- based on saline/wetland inventory of about 90% of District (Hecker and Bennett, 1983; Jensen, 1984; Harron, 1983)
13. Eastern	(10)	6	8		- based on saline/wetland inventory of about 70% of District (Harron, 1983; Jensen, 1985; Leskiw, 1983; Nicholson, 1985)

¹ Salinity Classes

Depth 0-2 ft. EC_e mS/cm

Depth 2-4 ft. EC_e mS/cm

Depth 0-4 ft. EC_e tons salt/acre

3	4	5
4-8	4-8	8-12
8-12	12-16	12-16
30	36	42

² Numbers in brackets are guesses based on general knowledge of the region. Other numbers are based on a study by Stanley/SLN Consulting (1978) (Districts 5 to 9) and saline/wetland inventories (Districts 12 and 13).

saline/wetlands within drylands vs irrigated lands are not distinguished. Also non-saline and saline wetlands are not separated. In irrigability classifications, soils rated Class 3 having salinity levels of EC 4 to 8 in the root zone (upper 2 feet) are mapped, but these are not included, unless they are wetlands, in the saline/wetland inventories. Also, there are unavoidable generalizations related to mapping and cartographic scales.

Estimated acreages of salt affected lands, as well as district and assessed irrigated acreages are given in Table 2. A total of about 840,000 acres, 25 percent, of land in southern Alberta irrigation districts is considered to be salt affected and/or waterlogged at levels that reduce crop yields substantially. Note that this includes natural saline and/or wetlands plus recently salinized and waterlogged lands. By salinity class some 325,000 acres (10 percent) is Class 3; 215,000 acres (6 percent) is Class 4; and 300,000 acres (9 percent) is Class 5. The total acreage is equivalent to about 75 percent of the present assessed irrigated acreage and 110 percent of the 1971 assessed irrigated acreage -- alarming indeed! Are the data reliable? About 3/4 of this salinity occurs within the Western and Eastern Irrigation Districts and these areas have, to date, had the most complete coverage and most reliable salinity surveys. The data base does not permit separation of pre-irrigation vs recent extents of salinity and wetlands. Although risky, tentative generalizations are possible. The wetland inventory (input to Alberta Land Base Study) indicated that in dryland areas, about 9% of the agricultural part of the South Saskatchewan Basin is affected by excess wetness (sheetwater, seepage, sloughs, marshes, watercourses). Sommerfeldt et al., 1984 determined that about 3.6 percent of the land in a large agricultural (dryland and irrigated) part of southern Alberta was naturally saline. If a third of the natural wetlands are saline plus 3.6 percent of the dryland then some 7 percent of the entire area may be naturally saline. On a

Table 2. Estimated Saline Acreages in Alberta Irrigation Districts.

IRRIGATION DISTRICT	BOUNDARY AREA	1983 ASSESSED IRRIGATED		ESTIMATED SALINE	
		Acres	Percent	Acres	Percent
1. Mountain View	6,800	3,710	55	700	10
2. Leavitt	16,530	4,440	27	1,700	10
3. Aetna	16,800	2,916	17	1,700	10
4. United	55,920	33,448	60	5,600	10
5. Magrath	23,840	12,357	52	4,500	19
6. Raymond	47,720	41,729*	87	10,500	22
7. Lethbridge Northern	205,200	116,745	57	28,700	14
8. Taber	112,080	72,971*	65	19,100	17
9. St. Mary River	389,160	319,712*	82	77,800	20
10. Ross Creek	4,640	1,776*	38	700	15
11. Bow River	194,080	181,174	93	38,800	20
12. Western	826,880	83,265	10	297,700	36
13. Eastern	1,477,000	244,099	17	354,480	24
TOTAL	3,376,650	1,118,342	33	841,980	25

(Column)** (1) (2) (3) (4) (5)

* 1984 Data.

** Calculation Procedures: (Numbers refer to columns)

a. $3 = \frac{2}{1} \times 100$

b. 5 = derived from Table 6 as a total of Class 3, 4 and 5 salinity levels

c. $4 = \frac{5}{100} \times 1$ assume homogeneous distribution of salt affected lands in irrigated and dryland areas

regional basis it follows that 18 percent, or 610,000 acres, of land has been salinized recently. This is equivalent to about 55% of the current assessed, irrigated acreage.

Future saline/wetland inventories would be more useful if a breakdown of acreages on a section basis were given, as follows:

Salt affected land by salinity class

- dryland
- wetland
- irrigated
- irrigable
- non-irrigable reclaimable

Since drainage and reclamation of saline/wetlands will also be considered in the future, the use and irrigability of surrounding non-saline lands and the drainability (permeability, outlets, costs, etc.) should also be noted at the same time. Note, that the land irrigability classification, present land use and saline/wetland inventories now provide all the information needed to give such a breakdown. It is simply a matter of tabulating acreages, as they are measured, in appropriate categories — an easy task using a computer. Extra costs of doing this are marginal, maybe 10%: the increased usefulness is immense.

Also to be considered is the use of an EM-38 for salinity detection at many points rather than sampling and lab analysis at a few points. This approach could greatly improve reliability at no extra cost per acre surveyed.

Level II irrigability classifications of quarter sections done in the last 10 to 15 years are another source of salinity information. These should be studied.

While refinements to mapping procedures can increase the accuracy of salinity mapping, there is absolutely no doubt that there will have to be much more land drainage and reclamation in the future. Are the salinized lands reclaimable considering physical features (permeability, outlets), economics, and environmental impacts (disposal of salts)? Neither soil survey, nor present and proposed land irrigability standards will answer these questions. Either the standards must be revised to encompass the dynamics of the total soil-water system or additional programs to answer these questions must be initiated. The basic landscape unit to be inventoried, analyzed and understood in making interpretations is shown in Figure 1. It must also include a "time" dimension, that is, soil-water balances in the pre and post irrigation environments.

RECOMMENDATIONS

What steps can be taken to ensure that we manage our land and water resources wisely? First, our land resource inventories and interpretations must deal with all the key issues/components. The following framework is presented for consideration, refinement and implementation:

1. Map scale:
 - for planning purposes, 1:20,000 or more detailed
 - for management purposes, 1:5,000 or more detailed
2. Baseline data:
 - soil survey - characterization of materials to at least 3 m
 - use of series names a must, for effective communication
 - wetlands and drainage courses - for drainage/reclamation
 - for wildlife habitat
 - for domestic uses
 - shallow groundwater flow systems
 - present land use and management practices (inputs, yields)
 - climatic conditions (re: moisture regime, adapted crops)
 - input costs and product prices

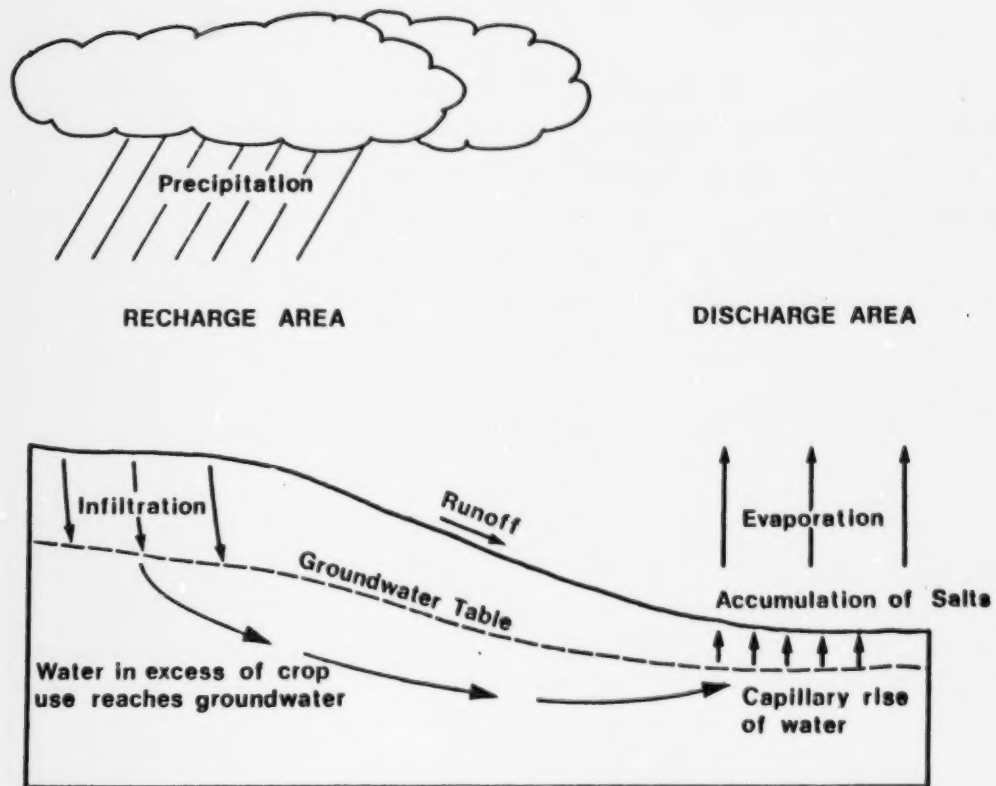


Figure 1. The basic landscape unit.

3. Integration and Interpretations:

Essential

- irrigation suitability
- crop water requirements (based on climate, soils, crops)
- potential for salinization
- land drainability/reclaimability
- benefit/cost analysis
- environmental implications, especially salt disposal
- development scenarios - full irrigation on block basis
 - irrigation of small tracts interspersed throughout dryland farming or grazing lands

Desirable (as applicable)

- soil erosion potential/conservation measures
- inputs to tax assessment, crop insurance, others
- dryland agricultural capability
- grazing capability
- wildlife habitat suitability

4. Final products:

- rating of land suitability for irrigation, given a water supply, based on technical/physical parameters
- economic feasibility of irrigation, may consider different scenarios
- environmental impact
- ratings for various land uses, in addition to irrigation, and
- recommendations for management

5. Support for on-going program:

- benchmark watersheds/fields for monitoring/modelling the soil-water system

- research activities to test special problems, for example, irrigability of sandy soils, shallow bedrock soils, etc. (such projects are underway now)
- extension effort to ensure findings of the land resource analysis are applied; good feed-back is vital to updating recommendations

6. Personnel:

- government steering committee to direct studies
- consulting teams comprised of specialists representing key disciplines working together on a project basis, inventory and research
- periodic reviews by producer groups to ensure applicability of results

7. Costs:

- Potential Savings
 - reduce soil sampling and lab analysis component in level III inventories, but increase field inspections and use EM-38
 - conduct level II surveys on a block basis rather than individual quarters
- Increases
 - shallow groundwater investigations
 - economics component
 - specialized interpretations as required

8. Benefits:

- technically sound land development and management ensuring sustained productivity
- sound economic basis for making investments
- environmentally safe development

I believe it is our responsibility to work together to ensure that the goal of optimal land use is achieved and maintained. This conference has allowed specialists in many disciplines, farmers, politicians and others interested in irrigation development to get together and broadcast achievements and to voice concerns. In light of the growing salinity problem and grim prospects for profit in agriculture, we must first expand our "soil horizons" to include the groundwater regime and economics considerations. If we can do this we can be optimistic about our future.

REFERENCES

- Francis, R.L., 1972. Irrigation Capital Works Report on Irrigation Development in Alberta, Past-Present-Potential. Water Resources Division, Alberta Environment.
- Harron, B., 1983. Eastern Irrigation District, Salinity/Wetland Inventory, Block 3a. Prepared for Alberta Agriculture.
- Harron, B., 1983. Land Irrigability Classification (Level III), Western Irrigation District. Blocks 4b, 4c and 6 (Saline/Wetland Inventories in Appendix B of each report). Prepared for Alberta Agriculture.
- Hecker, F.J. and D.R. Bennett, 1983. Western Irrigation District, Salinity/Wetland Inventory. Blocks 1, 2, 3 and 5. Alberta Agriculture.
- Harker, D.B., 1981. Problems associated with remotely detecting and monitoring saline sites within irrigated Alberta. Technical paper presented at the American Society of Photogrammetry, 47th Annual Meeting, Washington, D.C.
- Jensen, T.L., 1983. Magrath Irrigation District, Salinity/Wetland Inventory. Alberta Agriculture.
- Jensen, T.L., 1984. Western Irrigation District, Salinity/Wetland Inventory. Block 7. Alberta Agriculture.
- Jensen, T.L., 1985. Eastern Irrigation District, Salinity/Wetland Inventory. Block 4C. Gem Area. Alberta Agriculture.
- Jensen, T.L., 1985. Eastern Irrigation District, Salinity/Wetland Inventory. Block 3B, Bow Slope Area. Alberta Agriculture.
- Jensen, T.L., 1985. Eastern Irrigation District, Salinity/Wetland Inventory. Block 1A, Patricia Area. Alberta Agriculture.
- Leskiw, L.A., 1983. Eastern Irrigation District, Salinity/Wetland Inventory. Blocks 4A, 4B, 5, 6A, 6B, 6C, 6D, 8A, 8B. Prepared for Alberta Agriculture.
- Nicholson, B., 1985. Eastern Irrigation District, Salinity/Wetland Inventory. Block 2a, Rolling Hills Area. Alberta Agriculture.
- Peters, T.M., 1984. Eastern Irrigation District, Salinity/Wetland Inventory. Block 7D. Alberta Agriculture.

- Proudfoot, R.G., 1983. Western Irrigation District, Saline/Wetland Inventory. Block 4A, Langdon-Eagle Lake Area. Alberta Agriculture.
- Proudfoot, R.G., 1985. Eastern Irrigation District, Salinity/Wetland Inventory. Block 4D, Gem Area. Alberta Agriculture.
- Proudfoot, R.G., 1985. Eastern Irrigation District, Salinity/Wetland Inventory. Block 3C, Bow Slope Area. Alberta Agriculture.
- Proudfoot, R.G., 1985. Eastern Irrigation District, Salinity/Wetland Inventory. Block 1B, Patricia Area. Alberta Agriculture.
- Regier, H.F., 1972. Soil Capability for Irrigation within the Lethbridge Northern Irrigation District, Soil Classification Section, Irrigation Division.
- Regier, H.F., 1972-73. Soil Capability for Irrigation within the Raymond Irrigation District, Soil Classification Section, Irrigation Division.
- Sommerfeldt, T.G., M.D. Thompson and N.A. Prout, 1984. Delineation and Mapping of Soil Salinity in Southern Alberta from LANDSAT Data. Can. J. of Remote Sensing. Vol. 10, No. 2.
- Stanley SLN Consulting Ltd., 1978. Seepage and Salinization in Irrigation Studies: Efficiencies, Seepage and Salinization, Expansion Priorities. Consultant's report to Study Management Committee. Oldman River Basin, Lethbridge, Alberta.
- Vander Pluym, H.S.A. and H.A. Kerr, 1971. Tile Drainage Performance in a Lacustrine Discharge Area, 37 pages.

EFFLUENT IRRIGATION ON THE CANADIAN PRAIRIES

by

F. Frank Penkava
Department of Agricultural Engineering
University of Manitoba
Winnipeg, Manitoba, CANADA
R3T 2N2

The Concept of Effluent Irrigation

The fact that the practice called here "effluent irrigation" is often called "wastewater irrigation", "treated sewage land disposal", "sewage irrigation" or "wastewater application" indicates, that there exist several different approaches in the basic philosophy and in the way it is put in practice. It reflects the different interests behind the practices and may be indicative of the prevalence of one interest over another.

One of those interest is in disposing of an inevitable and from some point of view unwanted and difficult by-product of modern communal living and of various manufacturing processes. From this point of view, such effluent is "sewage" or "waste" and the understandably best solution is to get rid of it as quickly as possible and at the least cost to the producer of the effluent. If pursued selfishly, this effort may, and often did and does, cause damage to the environment and through it to other interests.

The protection of the environment from the damage caused by insensitive dumping of effluents either for commercial or for private reasons may represent a second area of interest which is often in direct opposition to the interests of the producers of the effluent. The demands of those interests may call for additional expenditures in treating the effluents and may also be pushed beyond reasonable limits.

Yet another approach to the effluent problem is to look at it neither as a waste nor a pollutant but as a resource and to utilize it to the benefit of the user of the effluent while offering easier solutions to the producer of it and removing most of the concerns of the protectionists. Effluent irrigation, that is the application of various types of effluents of suitable quality to agricultural land in a way that will benefit the production of crops, maintain the long-term fertility of the soil as well as the quality of the environment and which will not pose any special health risks, is the best way how to view the effluent as a resource, something that will be recycled, not disposed of.

Relationships, Benefits and Problems

While the introduction of the user of the effluent may appear as a solution to all problems and an end to all tensions and conflicts in reality it only makes the problem easier, but many details and balances in this symbiotic relationship must be resolved and fine-tuned before it may be called a success.

The broad definition of effluent irrigation given earlier talks about water of suitable quality. The first condition for workable relationship between the producer and the user of the effluent is that the producer treats the effluent to

such a degree that it would be suitable for irrigation in terms such as the total dissolved solids, chemical properties and pathogen presence. This aspect of the mutual relationship is usually not difficult to satisfy and producers of effluent are prepared to treat the water to such levels and take such necessary steps in the design or redesign of their treatment facilities to prevent accidental discharges of improperly treated effluent into holding lagoons and reservoirs from which water is taken for irrigation.

Cost sharing by the effluent producer with the farmer-user in the irrigation system may, however, be a more sensitive point of the relationship. Because effluent is usually available in areas where irrigation of certain crops may be beneficial or highly beneficial but dryland farming is also possible and profitable, the farmer will be interested in irrigation only if his costs are reduced. The effluent producer on the other hand can afford to cost share because spending money on irrigation may still be cheaper than otherwise necessary more elaborate treatment facilities and procedures and disposal facilities. The benefits to the effluent producer in terms of improved public relations and in maintaining the environmental quality for the producers' own people which are difficult to express in monetary terms are also to be considered and should make the effluent producer more generous in cost sharing.

The way the cost sharing usually is resolved is that the effluent producer provides the delivery of the effluent to the farm gate (the field). The producer of the effluent also frequently provides the system design either by his own engineering staff or by paying the consultants' fees and also takes care of the legal and regulatory aspects of the approval of the system.

This relation, while appearing sound and simple in principle, may lead to tension and conflicts when larger quantities of effluent are to be handled. From the farmers' point of view and in accord with proper irrigation practices, land should not be overloaded with effluent and only quantities equal to the gross irrigation water requirements (which include evapotranspiration deficit, the leaching requirement if necessary and the water losses in irrigation) should be applied. This may call for larger areas under irrigation and, therefore, more extensive, complicated and costly provisions to bring the water to the areas of consumption. The effluent producer may wish to suppress such tendencies and to push for higher applications which may border on or become poor irrigation practice and result not only in inefficient use of the effluent as a resource but in damage to the crop and soil and in serious farm management difficulties. Need for extensive effluent delivery and distribution systems can make the use of some large sources of effluent less efficient and non-attractive. Environmental concerns are usually alleviated if effluent is applied to the land rather than discarded into streams. However some new concerns, such as spray drift connected with sprinkler irrigation, concerns about surface runoff and groundwater pollution may surface. Those concerns may be raised not only by environmentalists, but also, and even more so, by health officials. Past research and practice proving that a properly designed and managed effluent irrigation systems are as safe and safer than many other human activities and that effluent irrigation has clearly a positive role in environment protection and can satisfy any health concerns.

Special Concerns and Measures

Based on the previous discussion it follows that the positive sides of effluent irrigation clearly prevail in all areas involved. However, the system must be properly conceived, designed and used.

The sensitive balance between proper irrigation practices and between effluent dumping is the principal condition.

As stated earlier, the water loadings must not exceed the gross irrigation water requirements and this may impose some special demands on the system and on the farmer as compared to regular "clean" water irrigation systems. While an irrigator who uses water from a well, stream or reservoir is not obliged to consume a predetermined quantity of water and can simply use less or no water in a wet year, this does not apply to effluent irrigation. In effluent irrigation all effluent produced (and there may be more of it in rainy years in many cases) must be utilized even if the need is lesser and the gross irrigation requirements are lower. In order to avoid overirrigation there must be some flexibility in the system and more land must be available to spread the effluent around. The system must, therefore, include the equipment or the structures and other facilities to achieve this goal. However, since this "reserve" land will not be irrigated on a regular basis, the cost of the additional equipment may be a problem. The alternate irrigation capacity should, therefore be located so that it does not require expensive permanent and yet seldom used water conveyance facilities. As much as possible it should be designed so that either portable (towable) equipment from the core irrigation area can be used or a different method of irrigation with less expensive equipment can be employed. A towable centre-pivot unit, traveller guns, side-roll or hand-move sprinkler systems may be examples of the first option, use of gated-pipe border or furrow irrigation of the second one.

While the many effluent irrigation systems in operation on the Canadian prairies and elsewhere have demonstrated that the health hazards to the operators and to the wider public are certainly smaller than those from many other human activities, some basic precautions should and must be taken. It has been a well accepted rule that the selection of crops irrigated with effluent must be limited to those which are not consumed by humans raw or if effluent irrigation is used in fruit orchards that such methods of irrigations are used in which the effluent does not contact the fruits. When irrigating pastures a quarantine period must be observed between the last irrigation and grazing. In designing effluent irrigation systems proper buffer zones must be kept or shelterbelts planted to prevent drifting of spray into inhabited areas, roads and even single dwellings.

Regular monitoring of the pathogenic aspects of the effluent may be useful but, unless conditions in the production of the effluent change, not necessary if the acceptability and reasonable safety of the effluent has been documented initially. However, in the case of an outbreak of any disease in the effluent producing community special precautions must be taken, the effectiveness of the treatment process under such special circumstances must be monitored and the irrigation operators cautioned and perhaps vaccinated.

Periodical monitoring of the effluent qualities as irrigation water, however, should be a routine at least in the spring before the season opens and the effluent stored over the winter is used and at least once later in the season when most or all of the stored water has been utilized and the effluent used for irrigation is mostly or exclusively the effluent produced only recently and treated perhaps only through the minimum retention period required.

Regular monitoring of soil conditions is a good practice in any farming operation. In effluent irrigation soil conditions should be monitored more frequently, perhaps in the fall after the harvest and in the spring. Research at the

Roblin (Manitoba) effluent irrigation site and elsewhere show considerable fluctuations in some soil characteristics with time.

In a summary effluent irrigation offers some special benefits such as the fertilizer in the effluent, reliable supply of effluent, cost sharing and other help in developing the system but at the same time puts higher demands on the managerial skills of the farmer, his understanding of the risks involved and his intelligent reaction to the complicated relations effluent irrigation brings along.

Development of Effluent Irrigation

The discussion of the origins and the development of effluent irrigation on a global scale could very well start as many school assignments do - with the old Egyptians, Romans and Greeks. However, the more significant and well documented history begins well over a century ago in England and in central Europe, particularly in Germany and in Poland. In the USA it expanded especially in the last fifty years and became both the solution to pollution and a respectable irrigation practice.

In all those developments the struggle for the sensitive balance between the needs of proper irrigation practices and the single-minded trends of sewage dumping can be observed. Lately, however, the proper use prevails and in some areas in the USA and in Europe the recycling of treated municipal and industrial effluent in irrigating agricultural crops became a well recognized part of sound water management.

In Canada and especially on the Canadian prairies the idea of effluent irrigation has not been accepted readily and as widely as it was elsewhere. The reasons for this were probably in the first place in generally lesser demand for irrigation, relatively easier access to irrigation water initially where irrigation was practiced, not very high concern about stream pollution and environmental impacts of sewage discharge in the past, concerns about long prairie winters and resulting demands on effluent storage capacities and the economic feasibility of effluent irrigation projects.

It was only in 1965 when an experimental effluent scheme was started in Medicine Hat and even after that the development was very slow with only four (registered) effluent irrigation systems added in the next eight years. Since then the increase in the number of the systems and in the area irrigated by effluent was significant and at present there are some 50 effluent irrigation systems with just over 3000 ha of irrigated land in the three prairie provinces of Alberta, Saskatchewan and Manitoba.

While the average size of the effluent irrigation systems on the prairies calculated on the basis of the totals is approximately 60 ha, this average is inflated by the size of a few very large systems such as the system near Moose Jaw with over 800 ha or Swift Current with roughly 300 ha. Most of the systems are much smaller and more than half of them irrigate less than 50 ha of land.

Sprinkler irrigation is by far the most popular method of irrigation and within the sprinkler irrigation methods the side-roll systems prevail over centre-pivots followed by traveller-guns and hand-move systems. There are only a few gravity surface irrigation systems, in some cases (Roblin, Man.) used only as an

alternative to be used in wetter years when the effluent needs to be spread over a larger area.

Alfalfa or alfalfa mixed with grasses and grasses alone are apparently the most favored crops, but crops such as corn or potatoes and occasionally other crops can also be found under effluent irrigation.

Potential for Further Development

As the doubts about the possibility of using effluent irrigation on the Canadian prairies have been proven unfounded and as some other circumstances are changing in favor of more effluent irrigation, effluent irrigation will with all likelihood gain more ground.

The reasons for its expansion and especially for more of the smaller effluent irrigation systems are in the increased shortages of water and increased pressures and needs for the protection of streamflow quality and general protection of the environment. The models of relations between the effluent producer and the farmer-user show that effluent irrigation can offer substantial economic benefits to both of them.

Considering the production of municipal effluent at an average rate of 275 L per person per day and the gross irrigation water requirements ranging from 250 mm in the more humid areas and years to 500 mm in the dryer conditions a municipality with 1000 inhabitants can supply valuable effluent for the irrigation of 20 ha under the more arid conditions and up to 40 ha in some other areas. This naturally represent a substantial, to a large degree yet unused potential which should be considered and addressed by all the parties involved directly that is the municipalities and the potential irrigators and those involved in less direct but not less important ways such as governments of all levels, agencies involved in water resources management, environmental protection agencies and interest groups and all citizens.

Principal Resource Literature

1. Nikolaichuk, W., M.R. Kechler, V.O. Biederbech and Y. James. 1982. Irrigation with Municipal Effluent: Nutrient Balance. In Wastes and Prairie Water Quality - Water Studies Institute Symposium No. 8 - Proceedings.
2. Penkava, F.F. and G.B. Murray. 1985. Impact of Irrigating Crops Using Municipal Effluent - The Roblin (Man.) Effluent Irrigation Study.
3. Penkava, F.F. and C. Ray. 1982. Soil Column Study of Irrigation Using Municipal Effluent. In Wastes and Prairie Water Quality - Water Studies Symposium No. 8 - Proceedings.
4. Pettygrove, G.S. and T. Asano (Editors). 1984. Irrigation with Reclaimed Municipal Wastewater. Department of Land, Air and Water Resources, University of California, Davis.
5. Wiebe, R. 1982. Sewage Effluent Irrigation Development in Saskatchewan. In Wastes and Prairie Water Quality - Water Studies Symposium No. 8 - Proceedings.

SESSION II

Maximizing Economic Crop Yields

Chairman: G. C. Jenkins



THE COMPUTER: AID TO MAXIMUM ECONOMIC YIELD

Paul O. Kresge

Abstract

Computer technology offers a means of managing and delivering the information we are accumulating on crop production. However, the large volume of information must be converted to computer language, called software, to take advantage of the delivery potential. Computer software like FLEXCROP and CROFILE is designed to assemble the information into packages that assist farmers with decisions about small grain production. Other existing software, including programs for irrigation scheduling and economic analysis may be integrated with the agronomic models. The computer programs consist of a model based on research data, and a user interface. The user interface should allow the non-scientist to extract useful information from the mathematical model, resulting in more profitable crop management decisions.

Steps in model development include problem definition; model outline; data assembly; delivery framework; model validation and verification; and project management. Though the steps often occur simultaneously and recursively, each is important to developing a useful product.

We are still in the early stages of developing crop management software. Database management systems and expert systems offer current solutions to some software problems. The field of artificial intelligence research will hopefully add to our arsenal of tools to facilitate application development. However, people are the key to successful projects. The need for recognition of contributions to team efforts, and the need for team management, must be met for integrated efforts to succeed.

1/ Agronomist, AgriBasics Company, Box 112, Belgrade, Montana.

Presented to "Irrigation on the Prairies", The Fourth Annual Western Provincial Conference: Rationalization of Water and Soil Research and Management. November 25-27, 1985. Saskatoon, Saskatchewan.

Introduction

My purpose is to examine computer technology as it relates to crop management. Selection of this topic to lead off the section on "Maximizing Economic Crop Yields" is significant in itself, for it underscores our perception of the power of these new tools. Few former technologies have generated so much interest, if not outright excitement, as small computers.

The reason for our excitement is clear, computers promise to help us organize and productively interpret information. All of us, whether scientist or farmer, recognize the enormity of our information base and our inability to utilize it effectively. Not only must we keep track of all of our information (data base management), but we also want to be able to use it to improve crop management. To do this requires not only information management, but also activities like synthesis, modeling, interpretation and delivery. Information, in this case about crop management, is a production input just like fuel or fertilizer.

Management and utilization of information for agriculture using the computer is at an infant stage of development. I hope that exploring some of the ways this development is taking place will provide a framework for ensuing discussions about maximizing economic crop yields.

The New Generalist

At a meeting in 1980, Dr. Lou Calpouzos, then head of the Plant and Soil Science Department at the University of Idaho, spoke eloquently of trends occurring in agricultural science (Calpouzos, 1980). Prior to World War II, scientists were characteristically generalists with a broad knowledge of a scientific discipline but without great depth of understanding. The era of the specialist from about 1945 until the mid-1970's used new technological tools of analysis which promoted in-depth knowledge within a narrow part of a discipline. The era of the "New Generalist", the point of Dr. Calpouzos' presentation, is characterized by putting together the breadth and depth of the two previous eras.

As Dr. Calpouzos stated:

"The New Generalist is a project manager who works closely with interdisciplinary teams of Specialists. This era is also characterized by a large use of computers and system analyses, and by quantitative experiments studying interactions between several factors as they affect yields. The task of the New

Generalist is to monitor the entire agroecosystem for a defined geographical area, look for management factors which constrain yields, and enlist the research and extension efforts of Specialists to relieve the yield constraints."

One of the features of the New Generalist's approach is the use of computers. A review of projects in the U.S. and Canada will show that there are many New Generalists at work in agriculture. They are using their computers to study systems, and to deliver management assistance. Rather than try to review all of these projects, I will share my experience with computer software developed for management of small grains.

FLEXCROP to CROFILE to ...

In 1978 Dr. Ardell Halvorson with USDA and I discussed how we might use AGNET, a computer system developed at the University of Nebraska, to provide detailed fertilizer recommendations to Montana farmers. We felt that the computer should offer more capability than simply a regurgitation of University fertilizer guide sheets. The task seemed formidable but we wanted to include as many factors as possible which affected the profitability of fertilizer. Our intent was to customize the recommendation for individual fields by considering agronomic and economic factors. After the program began to grow we realized that a broader domain of advice than fertilizer recommendations could be given. A major application has been in deciding whether to recrop or summerfallow in a variety of situations.

A flowchart of the FLEXCROP program is shown in Figure 1 (Kresge and Halvorson, 1979, Halvorson and Kresge, 1982). Stored soil water and expected growing season precipitation generate a yield potential for wheat, barley, oats or safflower. The yield estimate is then adjusted based upon management decisions about crop sequence; variety selection; weed control; nitrogen and phosphorus fertility; and seeding date. Based upon expected crop price and estimated production costs a projection of net profit can also be derived from the program.

We refer to the program as a delivery model. Our objective was to synthesize research data into a crop management tool rather than to develop a research tool. The project has been successful for several reasons: It demonstrates the capabilities of computers, it is educational, and it provides some management help. FLEXCROP is still in use and has led to some innovative software ideas elsewhere (Leholm and Vasey, 1983). However, it has some disadvantages as a management tool. The user enters data by responding to a long series of questions. Then, after sufficient data are entered the results are printed. To rerun the model with different data, even a small change of

one item, requires going through all of the questions again. Once the user becomes familiar with program operation, this constraint is cumbersome.

A prototype attempt to streamline the user interface is a program called CROPPFILE. A public domain version of CROPPFILE is available (contact P. O. Kresge) though publication of documentation is slow to materialize. Model algorithms are essentially the same as in FLEXCROP but the method of entering data and viewing results is substantially different. The program uses a spreadsheet format for data entry. Data items are organized as a series of worksheets (currently 6) as outlined in Figure 2. Figure 3 shows an example worksheet, in this case for nitrogen fertility. Changing a data item on any worksheet causes estimated yield and profit to be recalculated and the display updated. This format allows easy experimentation with management decisions and quick feedback of results. Other program options include printing of reports and the ability to save and reload disk files of program data. We have used the program successfully in the fertilizer business for exploring management options with farmers. The format allows easier use for decisionmaking though some of the educational value of FLEXCROP is diminished.

There are two major ways that the CROPPFILE prototype should be improved. First, the crop model itself must be improved by including additional factors and improving the existing equations. Some things that should be included, for example, are the effects of seeding rate and row spacing, tillage effects, and residue management. The existing model equations can always stand improvement, it just requires more research and time for data analysis. Second, CROPPFILE is hard-coded, that is, everything is programmed specifically for the FLEXCROP model data. Though easier to maintain than FLEXCROP, substantial reprogramming is necessary to add a worksheet or make modestly extensive changes. Some type of general modeling format should be developed to facilitate model building and updating.

As general, integrated packages develop there are many existing software tools which address specific management activities. For example, several irrigation scheduling programs have been developed. A program called SCHEDULE (Bauder, 1983) developed in Montana, is appropriate for the Canadian prairie. SCHEDULE evaluates available soil water-holding capacity, current soil water status, atmospheric demand, and crop water use to project future irrigation timing and quantity. A friendly feature of the program is the option of several degrees of complexity of input data. You can, for example, use resistance blocks, tensiometers, or soil probing to estimate current soil water. Four years of one major demonstration project showed that the technology was sound. However, farmers were slow to adopt computer scheduling. Intensive educational efforts and possibly direct economic incentives would be required to effect substan-

tial water savings (Hertzog and Bauder, 1983).

Other useful computer software deals with economic decisions and engineering of irrigation systems. Economic applications range from crop budget generation to evaluating pumping costs. Engineering applications include pipe sizing, pump selection and comparison of power sources.

The Task at Hand

Using computers for information delivery is an exciting new concept, particularly if the information results in more profitable decisions. A large body of data exists on irrigation management and crop production on the prairies. The task at hand is to assemble all of it into a management package delivered by a computer. Several stages are involved in the process.

Problem Definition

Some planning is required to determine the kind of output desired from the computer. In the case of FLEXCROP and CROFFILE, projected yield and profit are used as measures of the suitability of decisions. Decide who will use the program, and what types of management decisions will be addressed. Consider the time frame of the decisions. An irrigation scheduling program may require updating daily and make only short term predictions. A program for conservation tillage might consider several years at a time.

Model Outline

Once the concept of what a model will do is established, begin outlining the kinds of information which must be provided. Start with a list of the factors you know will effect the results you're interested in. Then think about practicality. An item should be relatively easy to measure or estimate. Factors which can't be managed may not be appropriate. For example, random events like hailstorms aren't predictable and can't necessarily be managed against.

Data Assembly

Literature review and regression analysis are obvious activities in data assembly. Less obvious, but more important, is what is referred to as model verification. The project team has to be comfortable that the equations being developed accurately describe the results of a decision. Discussion, argument and checking of other sources are frequent activities at this stage.

A concept I've found useful is reliance on "Best Available

Data". A fortunate circumstance is to be faced with a wealth of data from many well-run experiments. It's fun to apply an arsenal of statistical methods and arrive at a confident equation. The other extreme is a problem for which little or no data exist. Try to quantify some experts' opinions. Draw a graph of how the function should look and apply some numbers to the axes. Keep searching for better data and continuously validate the model, but don't stall the project on one item.

Generally, the model construction process provides direction for future research. Use the data assembly stage of model development to organize existing research information. Your notes will represent a "wish list" of data that can guide future decisions about what research should be done.

Delivery Framework

The overall delivery framework, or user interface, refers to the manner in which the user enters data and the way model results are given back. Ideas are still evolving as to the best ways to handle delivery. I've shown that FLEXCROP and CROFILE handle input/output quite differently for the same mathematical model.

There are some considerations that should influence the user interface:

1. User's don't often read manuals. The program should be self-explanatory. Help messages accessible during program operation are very useful and educational.
2. Data entry should be consistent. A simple thing like accepting a single keystroke in one place and requiring an "enter keystroke" after data entry elsewhere can be very confusing.
3. Check data as it is entered. Set limits for variables and use other techniques to compensate for lack of typing skills.

Model Validation and Verification

The first step in simulation development is to convert reality to a model (Bryan and Natrella, 1985). Validation is the process of ensuring that the model's results represent the system being modeled. Validation should be a continuous activity throughout model development and use. Before a model is used it must be thoroughly tested over a full range of input variables. Since a model is never finished, validation must be done during usage and each time a change is made to the program. Validation may require redesign of the model and, occasionally, extensive revision of the software.

A second task, after a model has been converted to a computer program, is verification. Verification requires checking to make sure the computer code does what you specify in the model. For example, suppose an equation in the model uses metric tons per hectare to evaluate crop residue. You can't enter short tons per acre and expect correct results. Verification changes usually don't require revision of the model, but rather careful debugging.

Project Management

Once you have embarked on developing a model, the steps I've outlined start to happen simultaneously and recurrently. It is easy to lose track of the project, particularly when the ideas really start to flow. Compounding the complexity is the necessity of building a team whose members will also have other commitments. I have a strong preference for building large integrated models because I feel that they will most effectively use the computer's power. However, it might be productive to begin some segments of the system as independent submodels. If this is done, make sure there is enough planning so that the submodels can be hooked together later on.

Future Trends

Recent history suggests that computer hardware; the integrated circuits, wires, and so forth will continue to provide plenty of power at a reasonable cost. In many cases people are not fully utilizing their present computer before it becomes obsolete and they jump to the newest and most sophisticated equipment. Integrated circuit memory costs serve as an example of hardware trends. In 1977, 16 kilobytes (16,000 characters) of random access core memory (RAM) sold for over \$500 U.S. or about \$31.25 per kilobyte. In 1985, a good buy in quality RAM was two million bytes (Lomas Data Products) for \$3795 U.S. or \$1.90 per kilobyte.

If hardware won't be limiting, then we need to find better ways to develop management software. The first step is to train and motivate the New Generalists and provide them with resources. New Generalists and teams of specialists have the ability to accomplish a great deal. However, two problems with getting the job done are lack of funding and the lack of professional recognition for team contributions. The right combination of skills must also be developed. We'll have to teach computer programmers about farming and teach agricultural scientists about computers.

If our training and communications needs are met, there are some promising trends which will greatly facilitate development of management models. Of these, research in Artificial Intelligence (AI) offers the most promise. The field of AI seeks to model human thought with computers. Some components of AI models are intelligence, reasoning, memory and experience. Most of the AI work must be considered very basic research without clearly defined applications. However, some currently useful applications have their roots in AI research. An example of AI software with potential for agricultural applications is the expert system.

An expert system is based on a body of knowledge, usually expressed as rules. When given a problem, the system sorts and combines rules to try to develop a conclusion. Some expert systems include PROSPECTOR for mineral exploration, MYCIN for medical diagnosis, DENDRAL for mass spectrum analysis in chemistry, and MOLGEN in genetics (Duda and Gaschnig, 1981). Truly intelligent computers may not be realized soon but the research is already spinning off useful tools and concepts. Our models may be able to "learn" rather than requiring reprogramming. This will speed model development. The recommendations provided by future software will also be more sophisticated.

I've neglected some exciting possibilities in this paper in order to focus on management software. For example, computers are being applied to processing and interpreting remotely acquired images. A satellite image of prairie cropland can be broken down by such things as crop acreage, soil type, and possibly even irrigated yield potential. Such image processing has attempted to assess wheat yields in the Soviet Union. Why couldn't remote sensing as its called, provide the basis for farm specific management plans? Several reasonably priced systems are available for sensing environmental data such as temperature, precipitation and soil water. It shouldn't be too hard to imagine a future-generation management software program getting data by remote sensing and environmental sensors and in turn controlling an automated irrigation system. It's fun to speculate about the possibilities.

References

- Bauder, J.W. 1983. SCHEDULE user's manual: Computer-assisted on-farm irrigation scheduling. Extension Bulletin 1273, Montana State University, Bozeman.
- Bryan, Otis F., Jr., and Michael C. Natrella. 1985. Testing large-scale simulations. BYTE. October, 1985, pp. 183-194.

Calpouzos, L. 1980. Future Prospectives of Loss Assessment. Proceedings, Workshop and Third Annual Meeting, Western Regional Coordinating Committee for Developing, Implementing and Coordinating Research on Crop Loss Appraisals. Reno, Nevada. (abstract).

Duda, Richard O., and John G. Gaschnig. 1981. Knowledge-based expert systems come of age. BYTE, September, 1981. pp 238-278.

Halvorson, A. D. and P. O. Kresge. 1982. FLEXCROP: A dryland cropping systems model. U.S Department of Agriculture Production Research Report 180.

Hertzog, Phillip J., and James W. Bauder. 1983. Irrigation scheduling in the Greenfields Irrigation District. Cooperative Extension Service, Montana State University, Bozeman.

Kresge, P. O., and A. D. Halvorson. 1979. FLEXCROP User's Manual: Computer-assisted dryland crop management. Extension Bulletin 1214, Montana State University, Bozeman.

Leholm, Arlen and E. H. Vasey. 1983. "CROPPACK", A short-run crop enterprise analysis program available on AGNET - A Management Tool For Agriculture. Cooperative Extension Service, North Dakota State University, Fargo.

CROP MANAGEMENT MODEL FLOW CHART

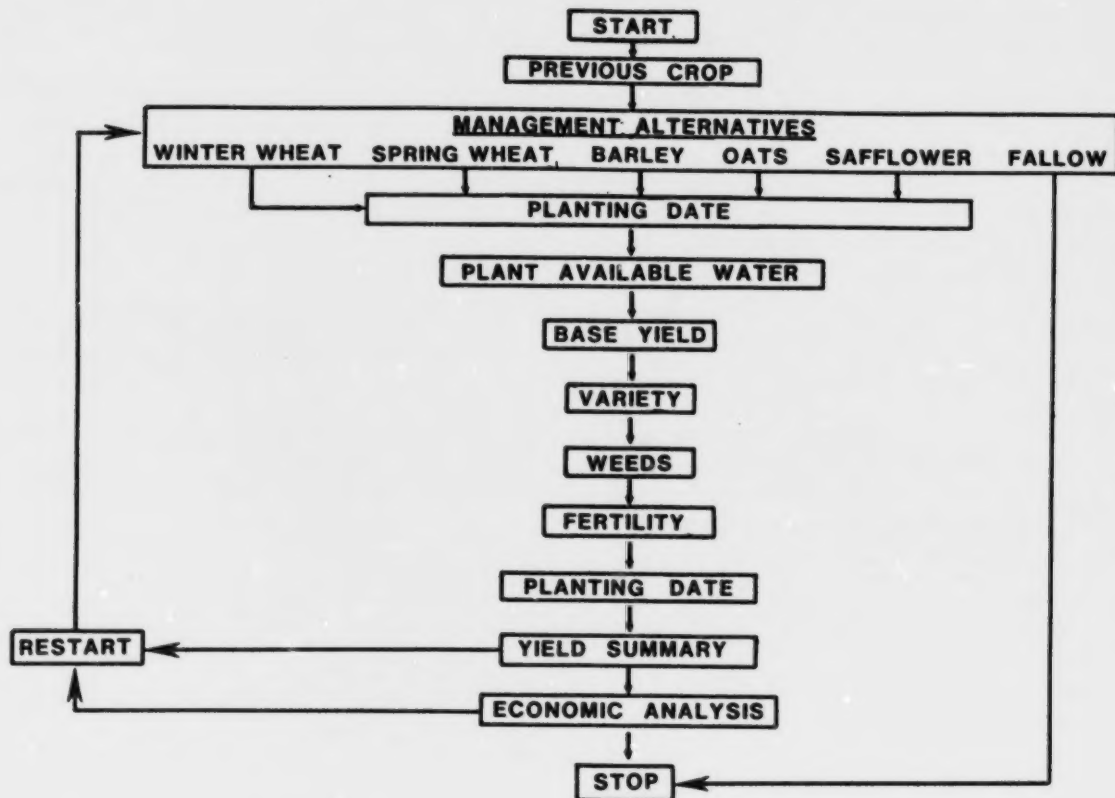


Figure 1. Flowchart of the FLEXCROP Computer Program

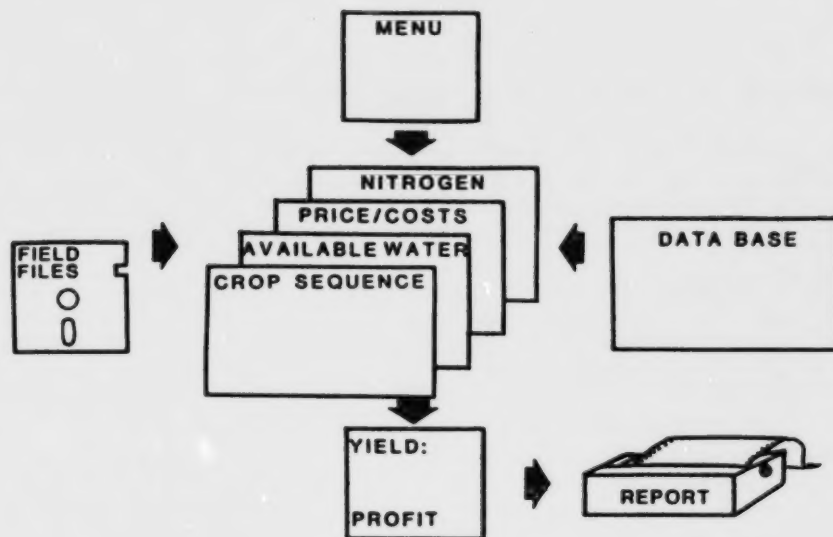


Figure 2. Components of the CROFFILE Computer Program.

NITROGEN SOIL TEST					
1	SURFACE SAMPLE DEPTH	8	INCHES		
2	SURFACE NITRATE:	4	ppm	POTENTIAL YIELD	: 66 BUSHELS
3	SECOND LAYER THICK.	16	INCHES	EXPECTED YIELD	: 42 BUSHELS
4	NITRATE LEVEL :	3	ppm	HIGH	: 5 BUSHELS
				LOW	: 5 BUSHELS
5	THIRD LAYER THICK.		INCHES		
6	NITRATE LEVEL :		ppm		
				NET PROFIT	\$ 135.15 /A
7	NITROGEN APPLICATION	50	LB/ACRE		
8	COST OF NITROGEN :	.23	\$/LB. N		

Enter item to edit (or Q to go to main menu) _

Figure 3. An Example Worksheet (Nitrogen Fertility) from the CROFFILE Program

SOME ASPECTS OF CLIMATE AS A VARIABLE AFFECTING IRRIGATION

by

C.F. Shaykewich, Department of Soil Science, University of Manitoba.

B. Grace, Agriculture Canada Research Station, Lethbridge, Alta.

H.W. Cutforth, Agriculture Canada Research Station, Swift Current, Sask.

D.M. Marantz, Alberta Soil and Feed Testing Laboratory, Edmonton.

The possible influences of weather and climate on irrigation are many and varied. On the one hand, climate determines the need for irrigation, while on the other, irrigation may itself influence climate. Since it would be impossible to deal with all aspects of this subject, we have restricted ourselves to just a few. These are:

- a) Fertilizer response under differing water regimes,
- b) The need for irrigation on the Prairies
- c) Climatic factors limiting crop yields under irrigation,
- d) Effect of irrigation on length of growing season required by crops, and
- e) Crop insurance data on crop losses

It would have been very desirable to have had the option of dealing with these subjects for the Prairie region as a whole, or at least on the basis of natural climatic boundaries. The fact is that political and not climatic boundaries determine what research and information is available. Therefore, for the most part, each of the above topics will be dealt with on a province by province basis.

Fertilizer Response under differing Water Regimes

Manitoba

Because soil water status varies from season to season and area to area, it is useful to know the response of crops to fertilizer under differing water regimes. One wants to ensure that the amount of fertilizer added will give the largest return on investment, i.e. that neither too much nor too little fertilizer is used.

Fertilizer response curves for Manitoba have been derived from decades of research. Each curve has been derived for a different water status. Marantz and Racz (1985. Personal Communication) calculated potential water use by the crop for the growing season. The first step was to calculate potential evapotranspiration (P.E.) from weather data. Using seeding dates and applying a biometecrological time scale to weather data to estimate stage of crop development, the consumptive use factors (C.U. = ratio of water that could be used by the crop to potential evapotranspiration) were calculated. These would typically have a value of about 0.3 at seeding to 1.0 when complete ground cover was achieved. Then seasonal crop water use was calculated according to the following equation:

$$\text{Potential water use} = \frac{\text{harvest}}{\text{seeding}} \sum [(\text{P.E.}) \times (\text{C.U.})]$$

Starting date for the calculations corresponded to seeding date for which soil moisture data was available. Actual water use by the crop was calculated by adding growing season precipitation to the difference in soil water between seeding and harvest.

$$\text{Actual Water Use} = \text{Soil water (seeding)} - \text{Soil Water(harvest)} + \sum \text{Precipitation seeding to harvest}$$

It was assumed that available soil water reserves could be depleted to one-half the potential value before any moisture stress occurred. In numerical terms, it was assumed that the available water holding capacity was approximately 200 mm. Therefore, there should be no moisture stress as long as 100 mm of available water remained in the soil. Such a condition was represented by a soil water status of 0.0, with positive values indicating more than adequate water, and negative values indicating a soil water deficit.

$$\text{Soil Water Status} = \text{Actual water use} - \text{Potential Water Use} + 100$$

Over a period of years, a number of combinations of soil water status and nitrogen supply (soil + fertilizer nitrogen) were investigated. The data were used to derive multiple regression equations estimating yield from soil water status and nitrogen supply. In turn, these equations were used to generate response functions shown in Figs. 1 - 4.

The data show that potential yield increases with increasing soil water status, the lowest curve is for a water deficit of 50 mm, while the highest is for a surplus of 150 mm. For Fergus barley (Fig. 1), for example, when water status is low, i.e. there exists a water deficit, then increases in yield due to fertilizer addition occur only up to about 60 kg/ha nitrogen supply. Additions of nitrogen beyond this level have virtually no effect on yield. If, on the other hand, the soil water status were 50 mm, a response to nitrogen fertilizer could be expected up to about 100 kg/ha nitrogen supply. Thus an improvement in soil water status which could be achieved by irrigation would suggest an increase in use of nitrogen fertilizer in order to achieve the higher potential yield.

Saskatchewan

Effect of timing of irrigation on fertilizer response It is a long recognized fact that the effect of water stress on crop yield depends to a very large extent on the physiological stage of growth at which the stress occurs. For example, using regression analysis, Baier and Robertson (1968) found that the highest correlation between yield and soil moisture occurred at the growth stage between jointing (just prior to emergence of the 5th leaf) and heading. Mack and Ferguson (1968) found that yields were most seriously reduced by moisture stress during the 5th leaf to soft dough stage. They also found that yields were affected much less drastically by moisture stress during the soft dough

to ripe stage. In his review of literature, Bauer (1972) concluded that water deficit at flowering of spring wheat probably had a greater effect on reducing grain yield than at any other growth stage. Baier and Robertson (1968) found that moisture stress during the planting to jointing stage had very little effect on the final grain yield.

It should not be surprising, then, to find that timing of water application in irrigation significantly affects grain yield. Henry and Hogg (1977) found time of irrigation application to be important in preventing yield reductions due to moisture stress at critical stages of crop growth. They observed the effects of four water treatments: A, missed first irrigation; B, missed second irrigation; C, received all irrigations, and D, rainfed; and six different levels of applied nitrogen: 0, 56, 84, 112, 168, 224 kg/ha; on the yield and protein content on three types of wheat: Sinton hard red spring wheat, Glenlea utility wheat, and Fielder soft wheat. The growing season precipitation was 189 mm and total water (irrigation + rain) for treatments A, B, and C was 505, 494 and 583 mm, respectively. All nitrogen was surface broadcast as ammonium nitrate (34-0-0) at time of seeding. Irrigation scheduling and amount of water applied was determined by tensiometers. Irrigation was applied when shallow tensiometers (15-20 cm) indicated a soil moisture tension of 0.5 bars. The amount of water applied was determined by readings from the deep tensiometers (30-45 cm) as indicated in Table 1.

Table 1. Amount of water applied to replenish soil moisture (Henry and Hogg, 1977).

=====	
Deep tensiometer Reading (bars)	Irrigation applied (mm)

0.3	64
0.3 - 0.7	89
> 0.7	114

Figure 5 shows the response of yield to applied N for the various water regimes for Sinton wheat. Although the level of response varied with cultivar, the pattern was similar for all three cultivars.

With little or no moisture stress (water regime C) yield showed a strong response to N. The response was reduced when stress conditions existed (water regimes A and B). Moisture stress early in the growing season (A) reduced the response to N more than the later stress treatment (B). There was no response to N under rainfed conditions.

Figure 6 shows the response of protein content of the grain to applied N for Sinton wheat. As with yield, the patterns of response were similar for all three cultivars. For a given moisture regime, protein content increased with increase in N. It also increased with increased water stress. Rainfed conditions resulted in the highest protein, followed by treatments A, B, and C, in that order. Thus, the

earlier the stress, the higher was the protein content.

The first three irrigation applications occurred on June 16-17, June 26-27, and July 4-5. Treatment C received all three applications, while treatment A missed the June 16-17 application and treatment B missed the June 26-27 application. It would have been very useful to know at what stage of growth these irrigations occurred. Since this data is not given, one must use literature data to make some estimates. Table 2 shows the average dates of occurrence for the specified growth from 1955 to 1965 at Brandon, Manitoba.

Table 2. Average dates of occurrence of phenological stages of wheat grown at Brandon, Manitoba. (1955-1965) (Mack and Ferguson, 1968)

Phenological Stage	Average Date
emergence	May 19
5th leaf	June 14
heading	July 5
soft dough	July 17
harvest	August 6

Comparing the dates in Table 2 to those for the irrigation applications, June 16-17 would approximate the time of jointing, i.e. the beginning of the jointing to heading (J-H) stage (Baier and Robertson, 1968). The jointing to heading stage would be approximately one-half complete by June 26-27. For irrigation treatment A, stress conditions would exist near the beginning of the J-H stage, while for treatment B stress would occur towards the middle to end of the J-H stage. Yield data (Figure 5) seem to indicate that it is critical to maintain adequate water supply during the J-H stage to prevent yield reductions due to moisture stress. Moisture stress (as imposed by this experiment) early in the J-H stage may reduce yields to a greater degree than moisture late in the J-H stage.

Schneider et al. (1969) applied a uniform amount of irrigation water to winter wheat at four growth stages: vegetative stage, V; boot stage, B; heading to flowering, H; and early grain development, G. For one application only, irrigation at the heading stage gave yields 52% of the maximum ('wet' treatment). A single irrigation at the other stages resulted in yields of only 25-35% of maximum. With two irrigations, the highest yields occurred for irrigation at E+H, with yields 75% of maximum. For three applications, the highest yields (90% of maximum) occurred at E+H+G or B+H+G combinations.

Central Alberta

A study on the interaction of soil fertility and water supply on yield of barley was conducted by Heapy et al. (1976). They related

barley yield (Y) to soil (Ns) and applied (Na) nitrogen, soil (Ps) and applied (Pa) phosphorus, a soil type variable (T), and an index of water stress (W) based on the number of stress days divided by duration of crop growth. The objective of their study was to define the most economical level of applied (fertilizer) nutrients to be used under given soil and water stress conditions. In the case of nitrogen, this was achieved by taking the first derivative of yield with respect to applied nitrogen:

$$\partial Y / \partial Na = 0.21938 - 0.00214 Na - 0.00100 Ns + 0.00033 Ps \\ - 0.0091 W + 0.00012 Na W$$

Assuming a price of \$3.85/quintal and a cost of \$0.22/kg of fertilizer nitrogen, Heapy et al. computed the optimum nitrogen application rate to be:

$$Na_{opt} = \frac{16224 - 100 Ns + 33 Ps - 913 W}{214 - 12 W}$$

Clearly, the greater the water stress, W, the lower is the optimum level of nitrogen fertilizer application.

Southern Alberta

The effect of the interaction of soil nutrients, especially nitrogen, and water supply is one of the major factors influencing crop quality and yields. Fertilizer yield response as a function of soil moisture in southern Alberta has not been fully investigated. Certainly, there is widespread agreement that farmers should adjust their N fertilizer rates depending upon the level of soil moisture. However, the degree to which rates should be adjusted is not clearly understood. The amount will depend upon the ability of the individual producer to deliver given amounts of water to the crop, and the yield-quality response functions of the particular crop.

Fertility - yield response functions for wheat (Read and Warder, 1974; Zentner and Read 1977) and barley (Heapy et al. 1976a,b) have been developed from fertility plot data and climatic factors for dryland situations. The importance of soil moisture as a factor affecting fertilizer-yield-quality responses has been emphasized by work with barley (Bole and Pittman 1980a,b), also under dryland situations.

The work of Bole and Pittman (1980a) is most instructive in the kind of technology that could be applied to irrigation. Working in Lethbridge, they used field studies to develop regression equations estimating barley yield (Y, kg/ha) as a function of spring soil-stored available moisture (Ws, mm), growing season precipitation (GSP, mm), and nitrogen fertilizer level (N, kg/ha). The value of these equations is that they can be differentiated so that change in yield with respect to change in input variables can be calculated. Thus for stored available water:

$$\partial Y / \partial W_s = 28.8 - 0.1574 W_s + 0.0257 N$$

indicating that yield increase depends upon both stored available water and fertilizer nitrogen. Note that the benefits of additional stored water are increased as fertilizer level increases. Similarly:

$$\partial Y / \partial GSP = -46.5 + 0.482 GSP + 0.080 N$$

Again, an increase in yield with increasing growing season precipitation depends upon N fertilizer level.

The change in yield with respect to change in N was given by:

$$\partial Y / \partial N = 0.256 - 0.0818 N + 0.0257 W_s + 0.080 GSP$$

This equation can be used to "optimize N levels for a desired GSP probability (risk) level." Nitrogen response curves are such that the cost of the initial increment of nitrogen (marginal cost) is less than the value of the additional grain produced (marginal return), i.e. the use of fertilizer N is profitable. As fertilizer N level increases, the marginal return decreases and some point is exactly equal to the marginal cost. This defines the most economic level of fertilizer application, Nopt. Using an example of \$0.50/kg N and \$0.07/kg barley:

$$\begin{aligned} \text{Marginal cost} &= \text{marginal return} \\ &= (\text{increase in yield}) \times \text{price of grain} \\ \$0.50 &= (0.256 - 0.0818 \text{ Nopt} + 0.0257 W_s + 0.08 GSP) \times \$0.07 \\ \text{Nopt} &= -84 + 0.31 W_s + 0.98 GSP \end{aligned}$$

Thus, Nopt depends upon both Ws and GSP, increasing by approximately 1 kg/ha for each mm increase in GSP.

Now, either Ws or GSP could be supplemented by irrigation. Thus, for a given level of irrigation, one can calculate the most economical level of N fertilizer that should be used. Similarly, one could determine the most economical level of irrigation that should be used.

Bauder et al. (1975) varied fertilizer and water levels to develop production functions. However, none of these studies quantified the effects of water and fertilizer application on the combined yield-quality response of an irrigated crop.

For irrigated land in southern Alberta, little information is available. Recent and unpublished data from Dr. J.B. Bole, Agriculture Canada Research Station at Lethbridge, are presented to indicate the interaction of water supply and nitrogen to crop yield and quality. Data are for only one growing season with Soft White Spring Wheat and hence are preliminary. Figure 7a depicts the variation in yields with different soil nitrate content and fertilizer application under an optimum irrigation regime (water was not limiting, i.e. the top 30 cm was always kept above 450 kPa tensiometer readings). With high nitrogen

and adequate moisture, yields of over 7 tonnes per hectare were achieved regardless of whether the nitrogen was derived from soil or fertilizer sources. Figure 7b displays the protein content achieved by the crop during the same experiment. The protein content never exceeded the acceptable level of 10.5% even at very high levels of nitrogen.

In the second portion of this experiment, irrigation was controlled to provide varying amounts of water ranging from 33 to 330 mm over the growing season (Fig. 8a). Soft wheat did not respond to nitrogen fertilizer at low levels of irrigation. As irrigation levels were increased, however, the yield response to nitrogen application became progressively more pronounced. Maximum yield was achieved only with simultaneous application of both high water and high nitrogen rates. These results illustrate the strong synergistic effects of nitrogen and water availability, and emphasize that maximum response to nitrogen fertilizer can be achieved only when irrigation is optimized.

Protein content was inversely related to irrigation level but positively related to nitrogen level (Fig. 8b). Nitrogen application under conditions of moisture stress resulted in protein content considerably higher than commercially acceptable levels for soft wheat. Adequate water application greatly reduced protein content even at high nitrogen levels.

Summary Statement on Fertilizer-Water Interaction

These brief examples indicate that more attention must be given to the investigation of fertilizer-water influences on yield-quality responses for the various crops and soils under irrigation in western Canada. The relationship between water supply and nitrogen is clearly a synergistic one. If either is limiting, then maximum yields will not be realized. It must be understood, of course, that there are limits to the response. Too much water or nitrogen can be detrimental to the crop. Crop response models combined with economic studies would ensure maximum high quality yields for the minimum expenditures of water and nitrogen. However, with adequate nitrogen and water, crop yields are limited by other factors. As many of our soils have an adequate supply of phosphorus (owing to the continued use of P fertilizer for the past number of years) and micronutrients, these factors do not appear to be as significant as in other areas. Assuming good management practices, the major factors limiting when fertilizer and water are not limiting are the genetic potential of the crop for productivity and climatic constraints.

The Need for Irrigation on the Prairies

Perhaps the best indicator of the relative need for irrigation on the Prairies is the map of soil water deficit prepared for the Agroclimatic Atlas Canada (Fig. 9). This map assumes 100 mm of readily available water in the soil on May 1. Then deficit is calculated by:

$$\begin{array}{lcl} \text{September 30} & & \text{September 30} \\ \text{Deficit} = \Sigma \text{ Potential evapotranspiration} & - & \Sigma \text{ Precipitation} - 100 \\ \text{May 1} & & \text{May 1} \end{array}$$

This map shows relatively low deficits in Manitoba (100 mm) and relatively high deficits in southwestern Saskatchewan and southeastern Alberta (300 mm). These numbers represent the amount of irrigation that would be required in order to satisfy evaporative demand in each region.

One must remember that this map represents the average conditions. As will be pointed out later, year to year variation can be quite considerable.

It should be pointed out that the highest water deficits are probably underestimated. The error lies in the assumption about soil water in the soil on May 1. As one moves from east to west, it is commonly observed that spring soil water decreases and would certainly be less than 100 mm in southeastern Alberta.

A second point is that the map represents irrigation requirement for only one type of crop - permanent forage which is actively growing throughout the entire period. The irrigation requirement of most crops, notably cereals, is considerably lower. To the authors' knowledge, a map of irrigation requirement for wheat, for example, for the entire Prairie region is not yet available.

Manitoba

Manitoba is generally considered to be the most humid of the three Prairie Provinces. This view appears to be substantiated by average annual precipitation (mm) values for some Prairie cities: Calgary, 442; Edmonton, 466; Lethbridge, 423; Regina, 384; Saskatoon, 349; Swift Current, 380; Brandon, 450; Morden, 530; Winnipeg, 526. Manitoba's relatively more humid setting would lead one to question the need for irrigation in this province. For cereal crops, one finds that on the average, only about 25-50 mm of additional water would be needed to maintain optimum soil water conditions for crop growth (Dunlop and Shaykewich, 1984). As a result, one is hard pressed to find any rationale for irrigating these crops in Manitoba.

The picture is somewhat different, however, when it comes to forage crops. For a crop like alfalfa, the first crop would require on the average about 25-50 mm of irrigation for maximum production. For the second cut, however, it would take on the average about 125-150 mm of irrigation to ensure maximum production (Fig. 10). If one is concerned about ensuring that one's irrigation system has adequate capacity, one may be interested in the 10% risk map (Fig. 11). This indicates that in one year out of ten, at least 225-300 mm of irrigation (roughly twice that of the average) have to be supplied to maximize production from the second cut. Clearly, then, year to year variability is an important factor to consider in irrigation planning.

Southern Alberta

The climate of the western plains is extreme continental, featuring short, warm summers and long, cold winters. Although this description is essentially true for the irrigated areas of southern Alberta, the proximity of the mountains usually protects much of the region from influences of the strong north-west winds associated with blizzard conditions farther out on the plains. The climate is dominated by warm, dry foehn or chinook winds. The comparatively high elevation also modifies the weather. These factors combine to reduce the severity and duration of winter cold periods and to alleviate the extreme summer heat. As a consequence, Lethbridge, for example, enjoys the highest winter and annual mean temperature on the Prairies, and yet is slightly cooler than many southern Prairie locations during the summer. There may be extended periods of above-average and below-average conditions, however, and extreme temperature fluctuations may occur within a very short time owing to chinook episodes. These characteristics make it unwise to assume that average conditions prevail at any specified time.

Crop Water Deficit Mean monthly evaporation from a Class A pan for the summer months at Lethbridge is shown in Figure 12. In all summer months evaporation from a free water surface is at least double, and often triple, the average precipitation. This indicates an overall moisture deficiency which, if maximum crop production is to be achieved, must be alleviated by supplementary water supplied by irrigation or, in the case of dryland situations, from stored soil moisture reserves.

Crop water deficit is generally accepted to be the difference between precipitation and potential evapotranspiration (PE). Potential evaporation cannot exceed free water evaporation under the same weather conditions. The concept of potential evapotranspiration has been so widely accepted that a detailed discussion of its meaning is not warranted. It is sufficient to say that there are several methods of calculating PE and that the methods seldom yield identical results. The more common methods in use in western Canada include some adaptation of the Penman, Thornethwaite, or Baier and Robertson formulae. Real evapotranspiration differs from the potential under certain circumstances. The reasons for these differences are best explained by the reference to the conditions imposed by the definition of PE and an analysis of the reality of these conditions.

Owing to the variation in precipitation from one year to the next, water deficits also vary with time. Table 3 displays average and extreme values of precipitation recorded at Lethbridge as an indication of the maximum possible variability. Extremes and averages, however, do not give a good indication of the normally expected variability in precipitation and hence, moisture deficit. For example, Figure 13 depicts a frequency histogram for May precipitation recorded at Lethbridge. Almost 70% of the data are found to be less than the mean. It is incorrect to suggest that Lethbridge can expect to receive, on average, the mean amount of precipitation. The probability of receiving

less than normal precipitation exceeds that of receiving greater than normal precipitation.

Table 3. Long term averages and extremes of precipitation (mm) during the growing season, 1902-1985. Agriculture Canada Research Station, Lethbridge, Alberta.

Month	Mean	Median	Greatest Precipitation		Least Precipitation	
			Amount	Year	Amount	Year
April	32.4	27.5	112.5	1967	0.5	1902
May	55.3	41.7	286.3	1902	2.3	1928
June	73.5	64.5	207.5	1953	2.0	1985
July	42.1	35.1	151.1	1902	1.5	1967
August	41.0	32.1	168.1	1978	1.5	1969
September	39.8	31.4	123.4	1925	0.0	1948

Climatic Factors Limiting Crop Yields Under Irrigation

Frost Free Period Perhaps the most important limiting factor for agricultural production on the Prairies is the length of the frost free period. Very few locations on the Prairies have a frost free period greater than 120 days (Fig. 14, from Longley, 1972). Most of the region where agriculture is practised has only about 100 consecutive days without frost. This severely limits the kinds of crops that can be grown on the Prairies. One of the implications to irrigation is that the shorter the season for a crop, the less water it requires to grow to maturity. All other things being equal, then, an area with a short frost free season is not as likely to benefit from irrigation.

Another serious problem faced by agriculture on the Prairies is the uncertainty of the length of the frost free period. Many farmers vividly remember that frost of August 26, 1982. Because of this frost, many crops did not reach maturity, while others suffered a severe drop in grain quality. It is true that a fall frost that early was an unusual occurrence; for example, at Brandon, Manitoba, one would expect a frost that early only once in 30 years. On the other hand, frost free periods substantially shorter than the average are quite common. Consider Portage la Prairie, Manitoba. The long term average frost free period is 125 days. In one year out of every four, one can expect the frost free period to be 115 days or less; in one year out of ten, it will be 105 days or less. Because of this tremendous variability, it would seem that maps of frost free period at a given risk, such as the one shown in Fig. 15, would be much more useful to farmers than any map showing averages.

Heat Requirements for Crops In addition to requiring a certain number of consecutive frost free days to reach maturity, most crops also

require a certain minimum amount of heat. We have all observed that crops develop slowly in periods when temperatures are cool. The heat requirement for crops has been quantified by calculating "Growing Degree Days", which are simply an accumulation of average daily temperature minus some base temperature from planting to maturity. For many crops grown on the Prairies, the base temperature of 5°C is used. Wheat, for example, requires about 1050 degree days above 5°C to reach maturity.

Maps of growing degree days above 5°C are available (see Dunlop and Shaykewich, 1984; Lewis et al., 1985). They show a general decrease from north to south, with areas of higher elevation showing lower growing degree day accumulation. When degree day requirement of crops is known, such maps may be used to decide where certain crops should be grown. Obviously, the growing degree day requirements of most cereals are met in the southern Prairies.

Many crops have more stringent heat requirements than cereal crops. Such is the case with corn, a crop which has more potential than cereals for benefitting from irrigation. The corn heat unit map for the Prairies (Fig. 16, Major et al., 1975), however, shows that, with currently available hybrids, grain corn production should probably be confined to areas in southern Manitoba and a small area near Medicine Hat. Since silage corn requires about 200 fewer corn heat units than grain corn, a substantial area of the Prairies could be used for its production. As earlier maturing hybrids become available, this map should be useful in defining those areas in which there exists a potential for corn, and therefore, a potential for irrigation of corn.

Risk Factors The poor harvest conditions for soft spring wheat of this past year dramatically illustrated the importance of risk factors to irrigated crops. Southern Alberta received more than twice the normal precipitation (190 mm vs a mean of 80 mm) for the August and September harvest period. The rainfall was evenly distributed at regular intervals so that crops could not dry in the fields for harvest. As a result of grain swelling and sprouting, the crop quality deteriorated. Very little of the harvest met Grades 1 and 2, most being downgraded to feed grain. As a result of the technical difficulties of processing soft spring wheat for feed in western Canada, much of the grain was transported to Ontario markets, thus further reducing the economic value of the crop to producers.

Such factors as untimely precipitation which may interfere with spring seeding or fall harvest operations can be statistically analyzed and appropriate probabilities calculated (see Table 4, for example). Other risk factors such as hail and frost can also reduce crop yield and quality. For example, the Alberta Hail and Crop Insurance Corporation annually pays \$30-50 million in hail damage alone for the province of Alberta. These parameters can also be statistically analyzed.

Table 4. Expected minimum number of working days for the period April 1 - June 2 on a heavy soil for selected sites on the Prairies.

Location	Certainty Levels							
	10%	20%	30%	40%	50%	60%	70%	80%
Brandon, Man	46.5	44.5	42.5	38.0	35.2	32.7	28.2	24.5
Melfort, Sask.	47.5	41.0	38.4	36.7	33.6	32.3	28.5	25.0
Regina, Sask.	59.5	54.5	49.5	44.0	41.1	35.0	31.5	28.0
Lacombe, Alta	56.8	55.0	53.2	51.4	48.5	42.0	39.2	35.0
Lethbridge, Alta	58.3	56.5	53.5	51.3	48.7	46.0	43.7	39.0

Source: Dyer, J.A., W. Baier, H.N. Hayhoe and G. Fisher. 1978. Spring field workday probabilities for selected sites across Canada. Agriculture Canada Technical Bulletin 86.

In an attempt to identify and quantify major risk factors affecting agriculture in Alberta, the Alberta Agrometeorology Advisory Committee defined four sub-risk categories; i) early fall frost, ii) excess spring moisture, iii) excess fall moisture, and iv) hail risk. Each risk was weighted equally. The composite risk factor to agriculture was mapped (Fig. 17) on a scale of 0 to 20, where higher values indicated increased risk.

The equal weighting of risk factors may be misleading. For example, certain areas of central Alberta have extreme risk of hail, whereas areas in the north have greater risk of early frost. It may be argued that a risk index should be weighted for specific risks and/or areas. Should excessive fall moisture, which interferes with harvesting operations and may reduce the quality of the crop, be weighted equally with hail, which totally destroys the crop? Although these problems are yet to be resolved, and further work on risk analysis is required, the composite index represents a good start to the evaluation of climatic risks for agriculture in Alberta.

Another area of climatic risks involves disease and insect infestations. Outbreaks of many of the major insect pests are closely related to climate. For example, the development of grasshoppers (Grace and Johnson, 1985), cutworms (Jacobson, 1971) and sugar beet root-maggot (Whitfield and Grace, 1985) are closely regulated by climate. However, much more fundamental research into climatic relationships of disease and insects is required before any climatic-pest/disease risk index can be developed.

Effect of Irrigation on Length of Growing Season Required by Crops

Crops grown under irrigation may require a longer time to grow from planting to harvest than those grown under rainfed conditions. Table 5 shows the date at which a given growth stage was reached and days from seeding for irrigated and rainfed conditions at Swift Current in 1985

(C.A. Campbell et al., 1985; Personal Communication). The crop was irrigated and fertilized for maximum production.

Table 5. Days after seeding and date on which given growth stages were reached for Neepawa hard red spring wheat and HY320 triple M wheat under irrigated and rainfed conditions.

Stage	Variety	Date Stage reached		Days after seeding	
		rainfed	irrigated	rainfed	irrigated
seeding	Neepawa	May 7			
	HY320	May 7			
emergence	Neepawa	May 17		10	
	HY320	May 18		11	
anthesis	Neepawa	July 6	July 11	60	65
	HY320	July 9	July 16	63	70
harvest	Neepawa	August 6	September 3	91	119
	HY320	August 12	September 11	97	127

For both varieties, the difference between harvest dates was approximately 30 days. The rainfed treatment was harvested in early August whereas the irrigated treatment was harvested in early September. This extended growth period may be critical in areas where frost free days are limiting, i.e. most of the Prairies. Under these conditions, earlier dates of seeding and other crop management practises may be required to mature the crop before the first fall killing frost occurs.

Crop Insurance Data on Crop Losses

Considerable insight into the problems that plague crop production with or without irrigation can be obtained by examining statistics on crop losses. Probably the best sources of data of this kind are the crop insurance corporations of the three Prairie provinces. Because of different political jurisdictions, it is not always possible to obtain comparable data from all three provinces. Hopefully what follows will provide an insight into the kind of information that is available, and that could, and should be used when considering irrigation.

Manitoba

The causes of crop losses for Manitoba for the period 1966-1984 are shown in Table 6. It is noteworthy that the long term average crop loss due to drought is 54%. It is clear, therefore, that a substantial portion of the crop losses could be averted by irrigation.

Table 6. Annual Causes of Crop Loss in Manitoba 1966-1984 expressed as % of total loss for each year. All crops - All province.

Year	Drought	Excess Moisture	Frost	Hail	Heat	Other	Total
1966	11.0%	82.0%	0.1%	6.4%	-	0.5%	\$ 669,010.16
1967	89.5	0.3	3.4	6.7	-	0.1	681,979.67
1968	7.6	47.3	39.7	5.3	-	0.1	2,260,394.33
1969	1.4	91.4	2.2	5.0	-	0.03	3,566,854.47
1970	12.0	58.4	11.3	8.8	-	9.6	1,932,065.65
1971	8.3	77.0	0.3	3.0	2.3	9.0	883,704.48
1972	45.9	6.8	22.9	17.0	-	7.4	876,808.46
1973	34.9	35.0	0.4	22.5	-	7.2	1,880,827.43
1974	90.6	2.4	3.1	2.1	-	1.7	7,436,557.45
1975	27.6	57.2	1.0	5.3	-	8.7	7,337,885.62
1976	56.0	30.0	0.02	8.0	-	6.0	5,725,372.73
1977	23.4	58.2	4.6	4.2	0.03	9.5	3,763,570.64
1978	41.7	39.0	5.4	11.4	0.3	2.3	2,571,307.80
1979	82.9	6.0	6.6	2.4	0.1	2.0	9,191,579.31
1980	80.6	7.7	7.4	0.6	1.5	2.2	52,176,274.00
1981	35.5	22.6	0.9	13.4	7.2	20.4	11,492,267.00
1982	9.6	6.4	70.1	5.8	0.1	8.0	17,018,722.85
1983	35.3	18.8	1.4	5.6	27.4	11.5	15,146,755.23
1984	60.4	8.0	1.6	6.6	5.7	17.7	17,028,310.91
Total \$Million	87.2	29.1	19.0	7.7	6.8	11.8	161,640,248.19
Total %	54.0	18.0	11.8	4.7	4.2	7.3	

The table also clearly demonstrates the substantial effect of year to year variation in weather on crop losses. Note that in 7 of the 19 years of record, more than 40% of the crop loss was due to excess moisture. Note also that in any given year, substantial losses can be attributed frost and hail. Obviously, these losses will not be averted by irrigation.

Table 7 illustrates the causes of crop losses in Manitoba in 1982 by risk area. The year 1982 must be regarded as abnormal because of the extremely early fall frost that occurred. Nevertheless, it is very significant that some risk areas had very large crop losses due to causes other than frost.

Table 7. 1982 Causes of Crop Loss in Manitoba expressed as % of total loss for each year. All crops by risk area.

Risk Area	Frost	Drought	Excess Moisture	Hail	Heat	Other	Total
# 1	46.3	26.4	1.4	9.0	-	16.8	\$ 263,629.87
2	77.3	2.6	2.5	14.1	-	3.5	1,692,898.18
3	42.8	45.1	0.1	8.1	-	3.8	757,353.51
4	86.1	2.0	0.5	6.1	-	5.3	995,916.17
5	86.2	0.4	3.0	1.4	0.02	9.0	1,815,732.09
6	91.7	1.6	0.5	1.2	-	5.1	1,860,883.62
7	29.1	58.1	0.8	11.6	0.2	0.1	842,731.08
8	47.4	11.0	13.2	1.6	-	26.7	465,340.80
9	55.1	31.0	4.1	7.1	0.02	2.7	1,585,670.20
10	76.7	1.0	0.3	8.0	-	14.0	2,264,780.93
11	65.7	2.5	7.8	7.9	-	16.1	1,104,330.35
12	70.4	1.1	15.6	2.6	0.03	10.2	2,097,074.24
14	63.8	-	33.1	1.2	-	1.9	597,569.89
15	51.3	1.5	41.1	0.7	-	5.4	553,467.31
16	88.2	-	0.7	7.2	-	3.9	122,344.61
\$ Million							
1982	11.9	1.6	1.1	1.0	0.003	1.4	17,018,722.85
%	70.1	9.6	6.4	5.8	0.1	8.0	

The variation from one risk area to the next is illustrated by comparing risk areas 6 and 7. These occur side by side, yet the losses from different causes are vastly different. Statistics like these for the entire period would be very useful as a basis for policy decisions as to where irrigation projects should be encouraged.

Saskatchewan

The crop loss data for Saskatchewan for causes other than drought is shown in Table 8. The losses due to poor seeding and harvest conditions and frost over the period of record are in the order of 15%. These are losses that, over the long term, could not be averted by irrigation. It is assumed that the losses not accounted for in the table are in the main due to drought. This leads one to the conclusion that in excess of 80% of the crop losses in Saskatchewan could be prevented by irrigation.

Table 8. Annual Causes of Crop Loss due to poor seeding and harvest conditions, and frost in Saskatchewan 1975-1984 expressed as % of total loss for each year. All crops - All province.

Year	.. Quantity Losses due to..				Total Quality	Total	Total
	Flood	Frost	Excess Rain	Snow	All Causes	Previous Columns	Indemnity Paid
1975	1.77	3.23	8.79	-	3.35	17.14	\$ 25,014,923
1976	2.80	0.08	11.50		0.26	14.64	21,716,088
1977	0.31	9.75	3.17	0.02	5.11	18.36	36,617,757
1978	0.69	7.37	2.55	0.01	2.80	13.42	28,924,897
1979	0.27	15.30	1.50	-	7.12	23.65	102,833,213
1980	0.02	2.50	0.03	-	2.96	5.51	135,202,260
1981	0.09	0.18	0.31	-	1.23	1.81	91,159,760
1982	0.50	20.20	1.60	0.09	9.09	31.48	72,912,340
1983	1.30	0.05	7.30	0.03	8.70	17.38	104,635,341
1984	0.03	0.06	2.10	0.01	1.40	3.60	253,558,148

Although the data are not shown, the variation in the extent to which a particular cause is responsible for crop loss with risk area is very large, similar to that shown for Manitoba. This area to area and year to year variation become very important in arriving at a policy with respect to irrigation.

Alberta

For Alberta, only data for the 1984 crop year were available (Fig. 18). They show that over 80% of the crop losses were due to drought. One has to recognize, of course, that 1984 was drier than normal. This kind of data for a number of years and over a number of risk areas would be required to obtain a more accurate picture of the place of irrigation in Alberta agriculture.

Summary

1. Fertilizer, particularly nitrogen fertilizer greatly modifies the crop response to irrigation. Usually higher amounts of nitrogen fertilizer will be required under irrigation if maximum returns to the farmer are to be realized.
2. The need for irrigation generally increases as one moves from east to west in the Prairies. There are very large variations in this need from year to year. Crop type is just as important in establishing need for irrigation as is climate.
3. Climatic factors such as length of frost free period, and heat unit accumulation, place severe restrictions on the kind of crop that can be grown in Western Canada. This in turn limits the potential for

irrigation on the Prairies.

4. Preliminary results show that irrigation may significantly extend the growing season requirement of crops, to the point that a crop under irrigation may not be able to mature in time to avoid fall frosts.
5. Data from the Crop Insurance Corporations of the Prairie provinces indicates that more than half the crop losses are due to drought. There are substantial year to year and risk area to risk area variations.

Acknowledgment

Much of the information contained in this manuscript was compiled by people other than the authors. We would like to thank most sincerely: S. Dupuis, Alberta Environment; M. Swan, Manitoba Crop Insurance Corporation; G.W. Falk, Saskatchewan Crop Insurance Corporation; and R.A. Rains, Alberta Hail and Crop Insurance Corporation. These individuals were extremely helpful. Because of space limitations, only a small sample of the information they provided could be presented.

LITERATURE CITED

- Agrometeorology Research and Service Section, Land Resources Research Institute, Agriculture Canada. 1975. Agroclimatic Atlas Canada.
- Baier, W. and Robertson, G.W. 1968. The performance of soil moisture estimates as compared with the direct use of climatological data for estimating crop yields. *Agric. Meteorol.* 5:17-31.
- Bauder, J.W., Hanks, R.J. and James, D.W. 1975. Crop production function determinations as influenced by irrigation and nitrogen fertilization using a continuous variable design. *Soil Sci. Soc. Amer. Proc.* 39:1187-1192.
- Bauer, A. 1972. Effect of water supply and seasonal distribution on spring wheat yields. Bulletin 490. Agric. Exp. Station. North Dakota State University, Fargo, N.D.
- Bole, J.B. and Pittman, U.J. 1980a. Spring soil water, precipitation and nitrogen fertilizer: Effect on barley yield. *Can. J. Soil Sci.* 60:461-469.
- Bole, J.B. and Pittman, U.J. 1980b. Spring soil water, precipitation and nitrogen fertilizer: Effect on barley grain protein content and nitrogen yield. *Can. J. Soil Sci.* 60:471-477.
- Dunlop, S., and Shaykewich, C.F. 1984. Southern Manitoba's Climate and Agriculture. Manitoba Department of Agriculture.

- Grace, B. and Johnson, D.L. 1985. The drought of 1984 in Southern Alberta: Its severity and Effects. *Can. Water Res. J.* 10:28-38.
- Heapy, L.A., Webster, G.R., Love, H.C., McBeath, D.K., von Maydell, U.M., and Robertson, J.A. 1976. Development of a barley yield equation for central Alberta. 2. Effects of soil moisture stress. *Can. J. Soil Sci.* 56:249-256.
- Henry, J.L. and Hogg, T.J. 1977. Nitrogen and water requirements of hard wheat, utility wheat and soft wheat. *In* Soil plant nutrient research report (No. M57). Ed. J.L. Henry and T.J. Hogg. Department of Soil Science, University of Saskatchewan, Saskatoon, Sask.
- Jacobson, L.A. 1971. The pale western cutworm, Agrotis orthogonia Morrison (Lepidoptera: Noctuidae): A review of research. *Quar. Entomol.* 7:411-436.
- Lewis, D., Heywood, R., Dupuis, S., Mills, P. and Hume, Wm. 1985. Agroclimatic classification for Alberta. Alberta Agrometeorology Advisory Committee.
- Longley, R.W. 1972. The Climate of the Prairie Provinces. Climatological Studies No. 13. Environment Canada, Atmospheric Environment.
- Mack, A.R. and Ferguson, W.S. 1968. A moisture stress index for wheat by means of modulated soil moisture budget. *Can. J. Plant Sci.* 48:535-543.
- Major, D.J., Pelton, W.L., Shaykewich, C.F., Gage, S.H., and Green, D.G. 1976. Heat units for corn in the Prairies. *Canadex* 111.070.
- Read, D.W.L. and Warder, F.G. 1974. The influence of soil and climatic factors on fertilizer response of wheat grown on stubble land in southwestern Saskatchewan. *Agron. J.* 66:245-2148.
- Schneider, A.D., Musick, J.T. and Dusek, D.A. 1969. Efficient wheat irrigation with limited water. *Trans ASAE* 12:23-26.
- Whitfield, G.H., and Grace, B. 1985. Cold hardiness and overwintering survival of the sugarbeet root maggot (Diptera: Otitidae) in southern Alberta. *Ann. Entomol. Soc. Amer.* 78:501-505.
- Zentner, R.T. and Read, D.W.L. 1977. Fertilizer decisions and soil moisture in the Brown soil zone. *Canfarm Econ.* 12:8-13.

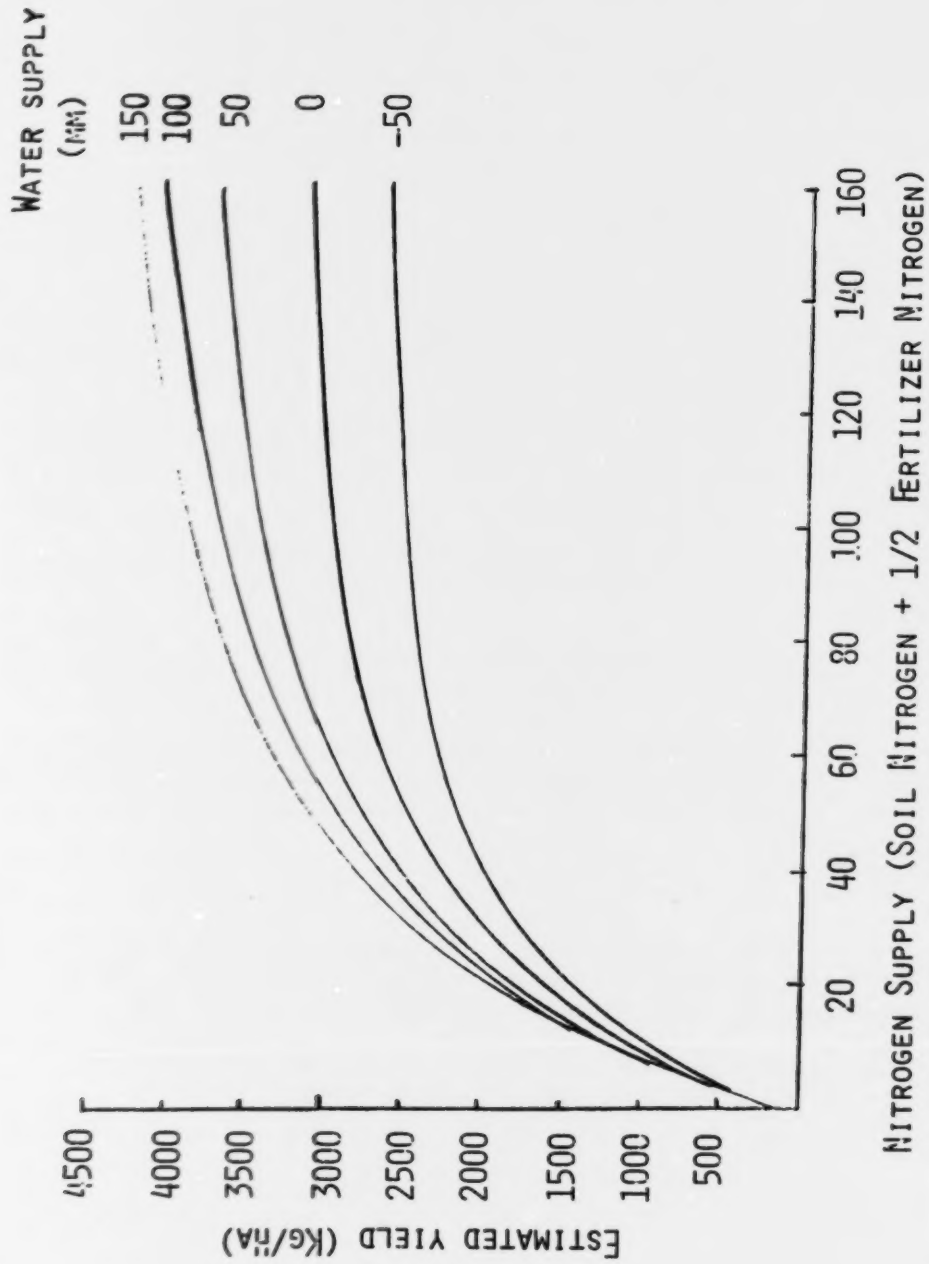


FIGURE 1. EFFECT OF NITROGEN SUPPLY AND WATER SUPPLY ON YIELD OF CONQUEST BARLEY.

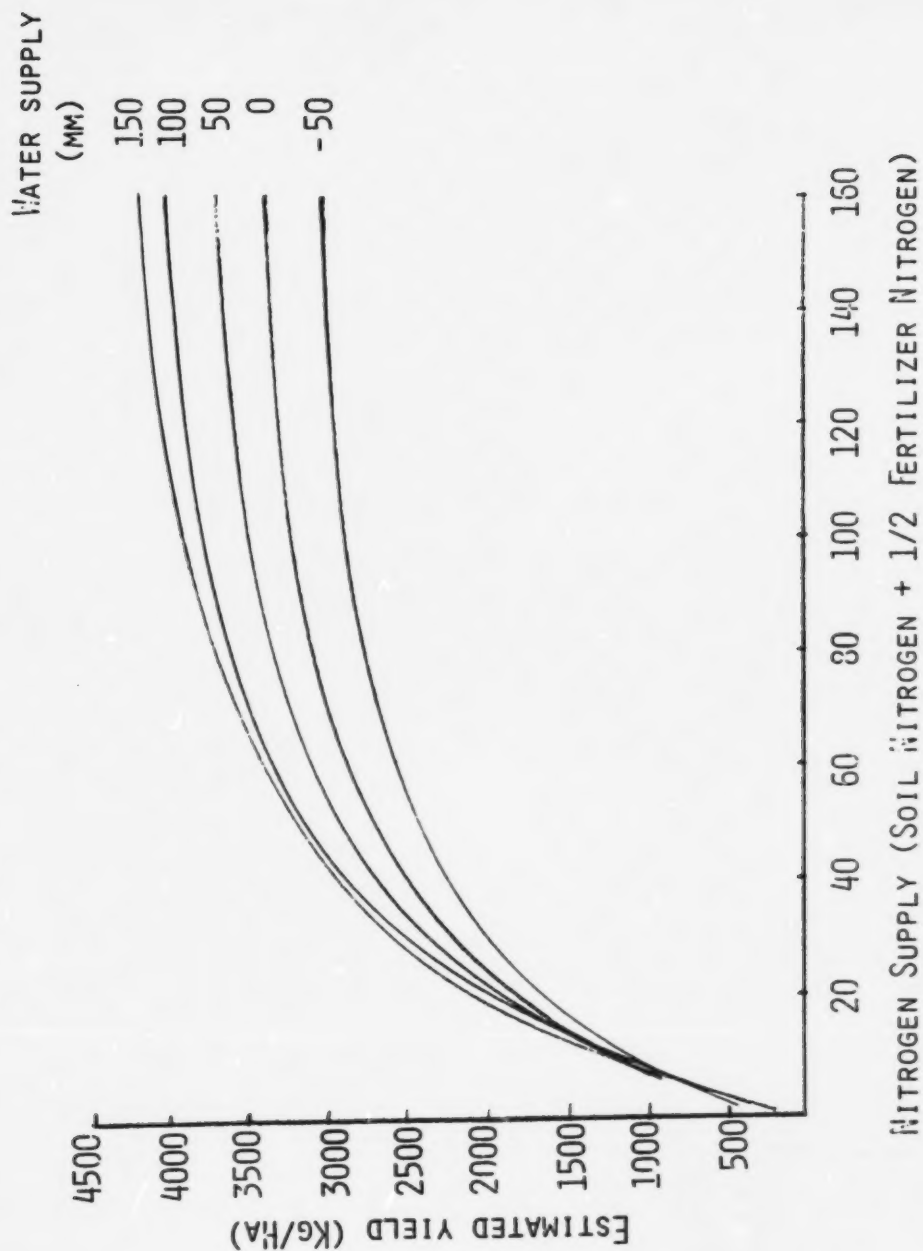


FIGURE 2. EFFECT OF NITROGEN SUPPLY AND WATER SUPPLY ON YIELD OF FERGUS BARLEY.

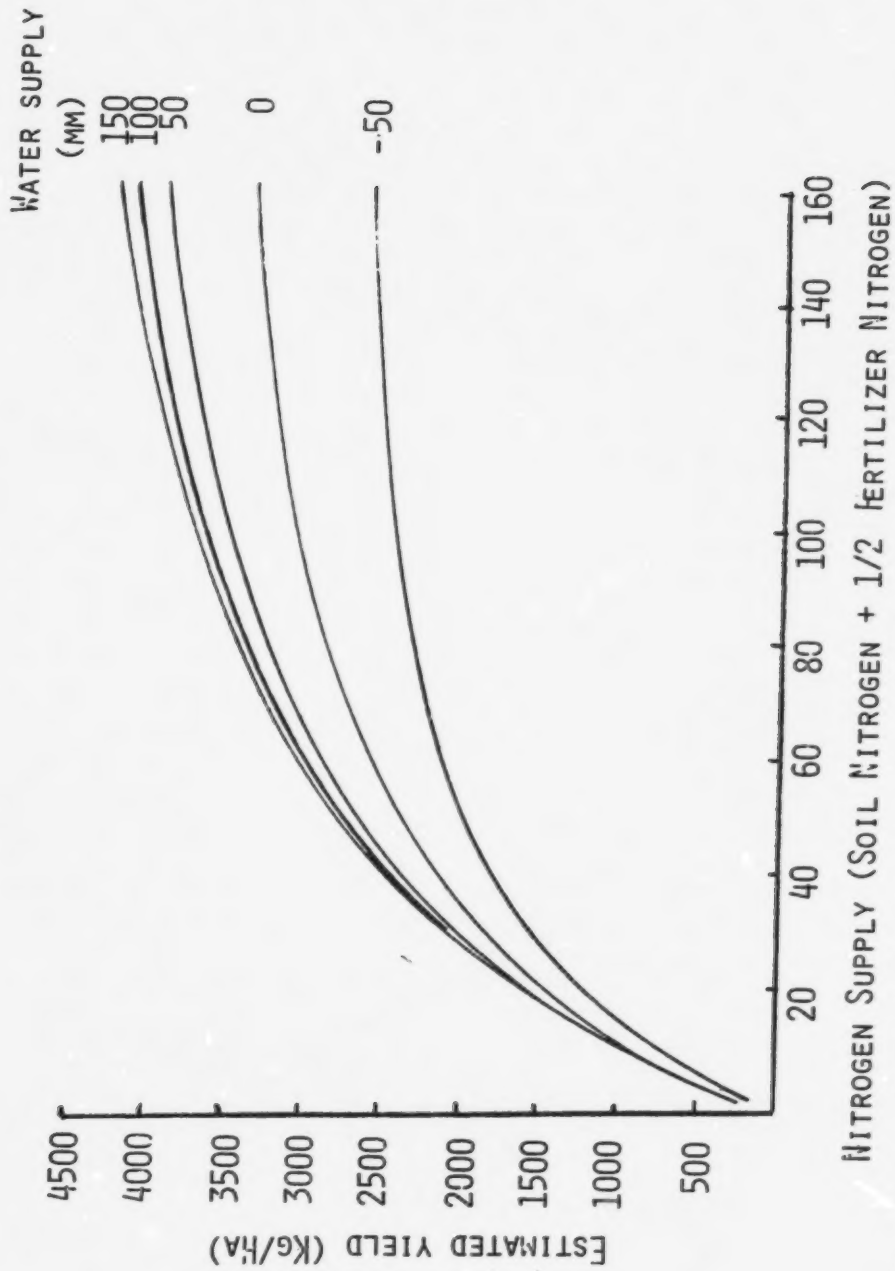


FIGURE 3. EFFECT OF NITROGEN SUPPLY AND WATER SUPPLY ON YIELD OF NEEPAWA WHEAT.

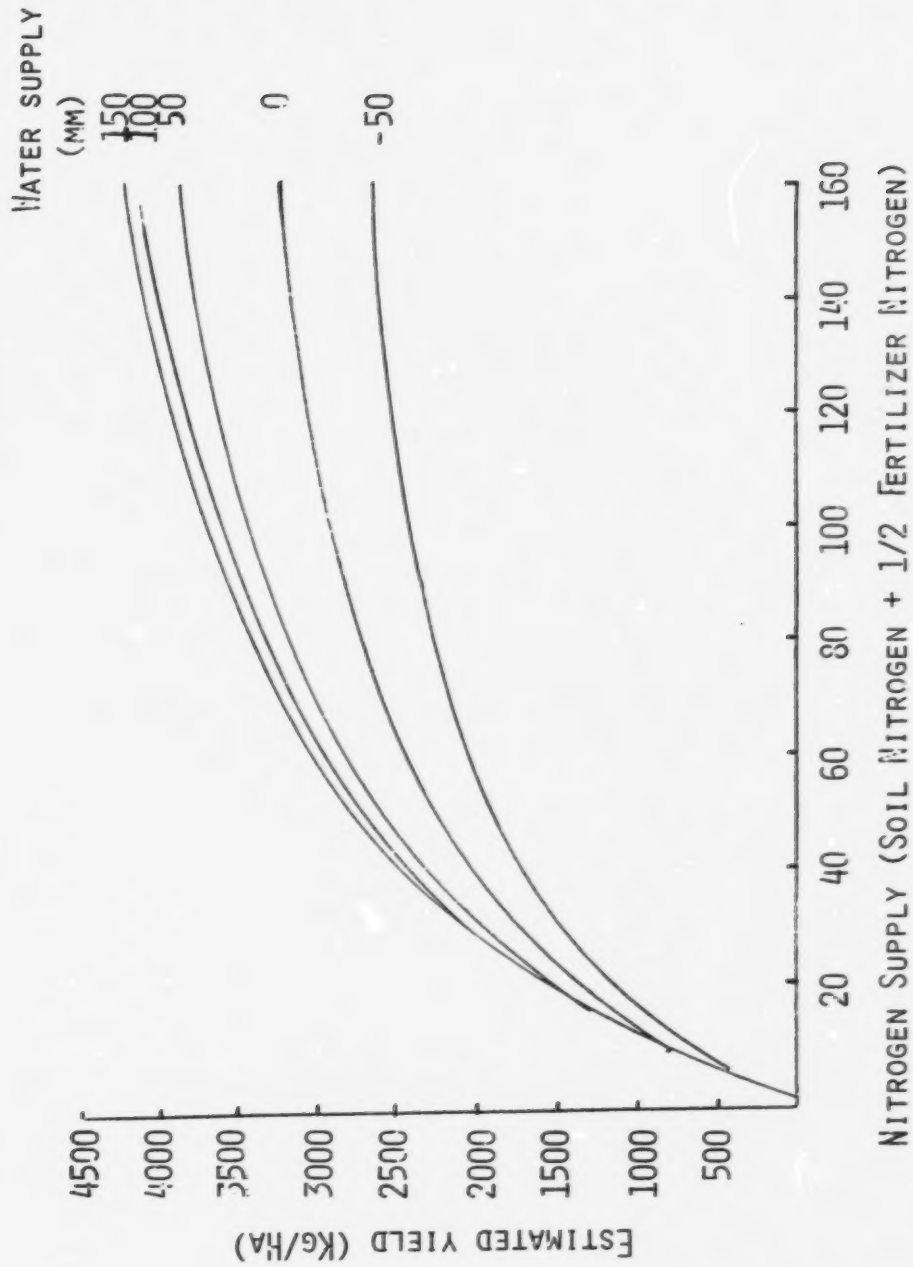


FIGURE 4. EFFECT OF NITROGEN SUPPLY AND WATER SUPPLY ON YIELD OF GENLELE WHEAT.

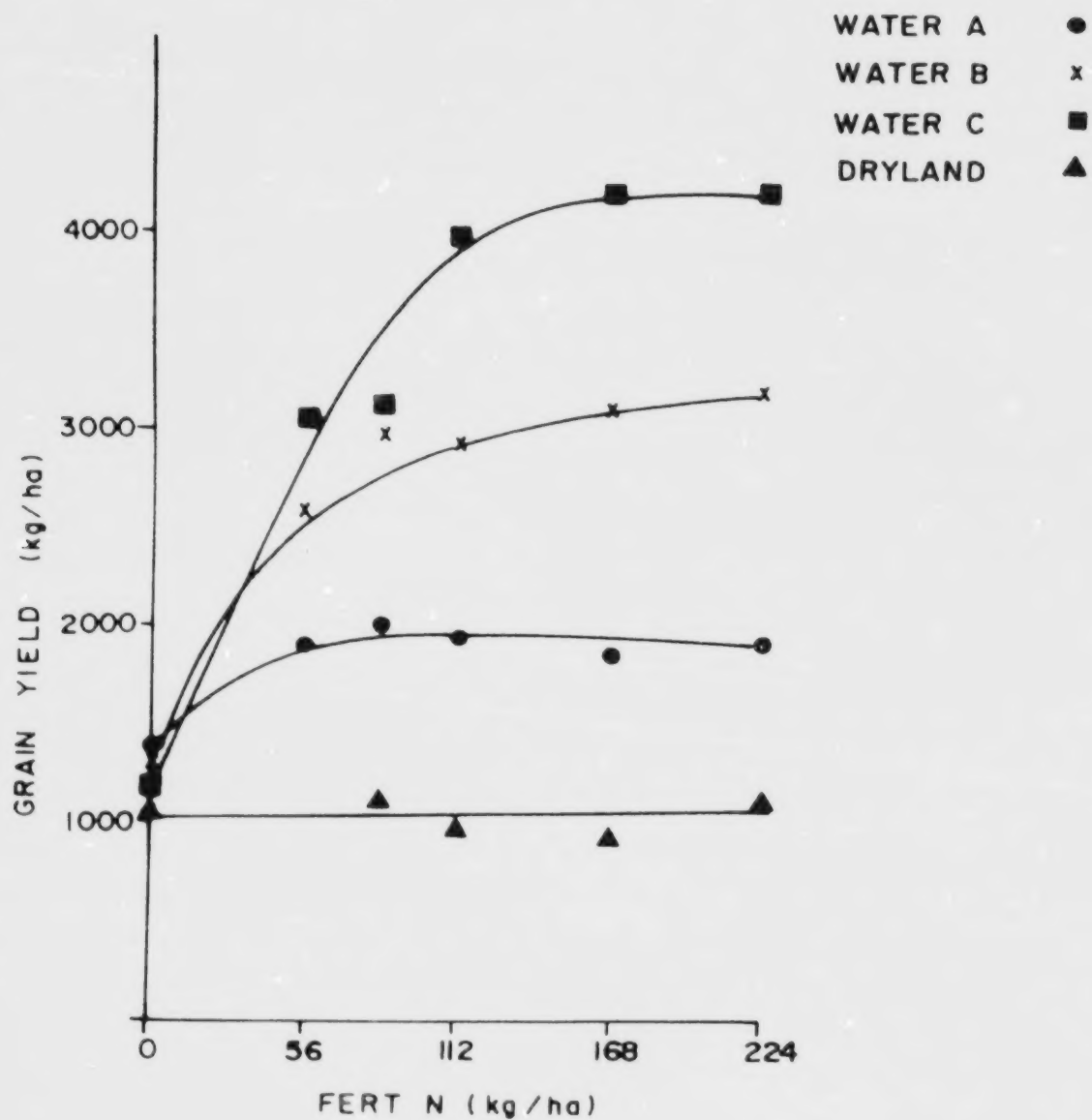


Figure 5. Grain yield as a function of fertilizer nitrogen under dryland and three irrigation regimes: Water A missed June 16-17 application, Water B missed June 26-27 application, Water C received all applications. Total water used: Water A - 505 mm, Water B - 494 mm, Water C - 583 mm, dryland - 189 mm (Henry and Hogg, 1977)

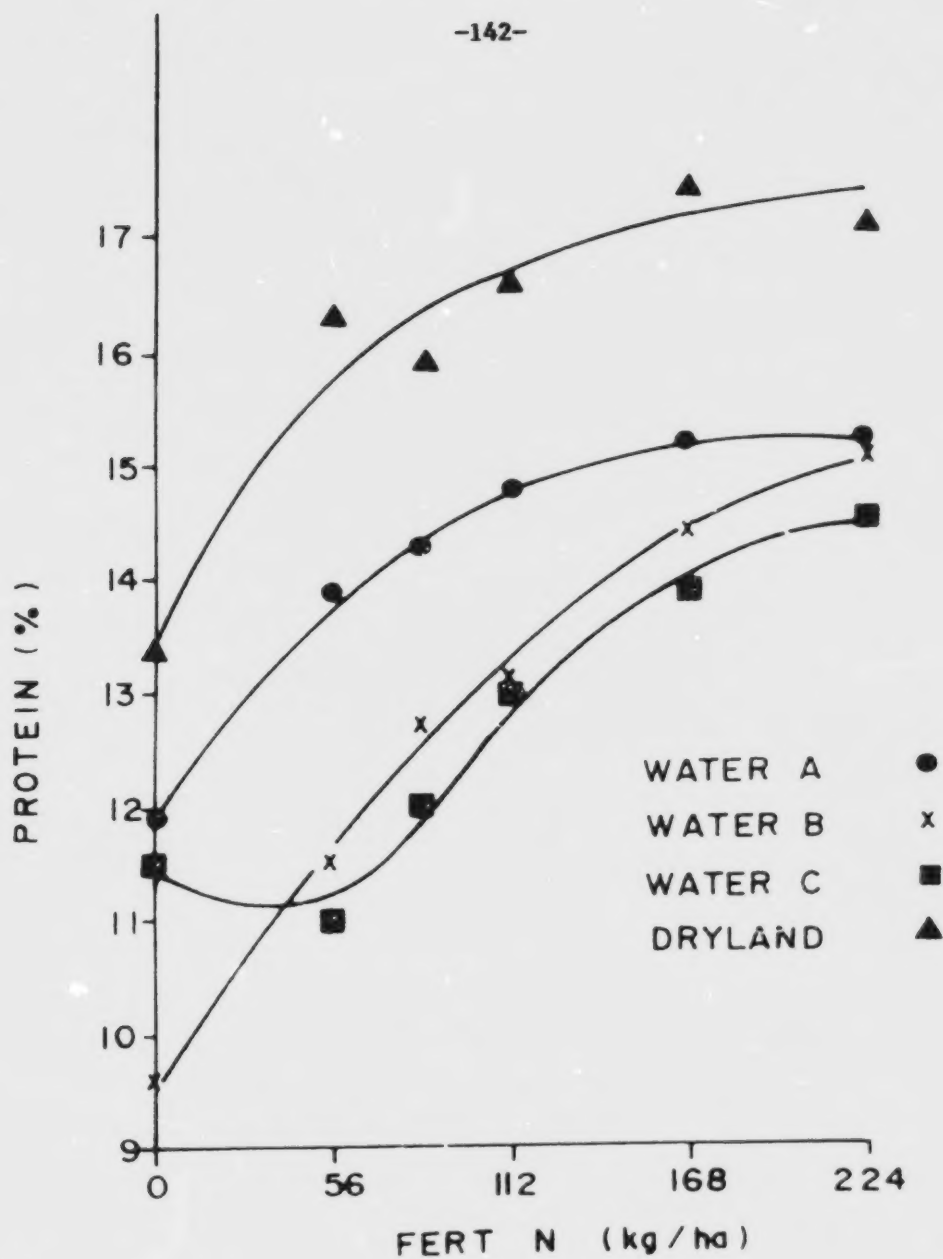


Figure 6. Protein content as a function of fertilizer nitrogen under dryland and three irrigation regimes. Water treatments are the same as those in Fig. 5. (Henry and Hogg, 1977).

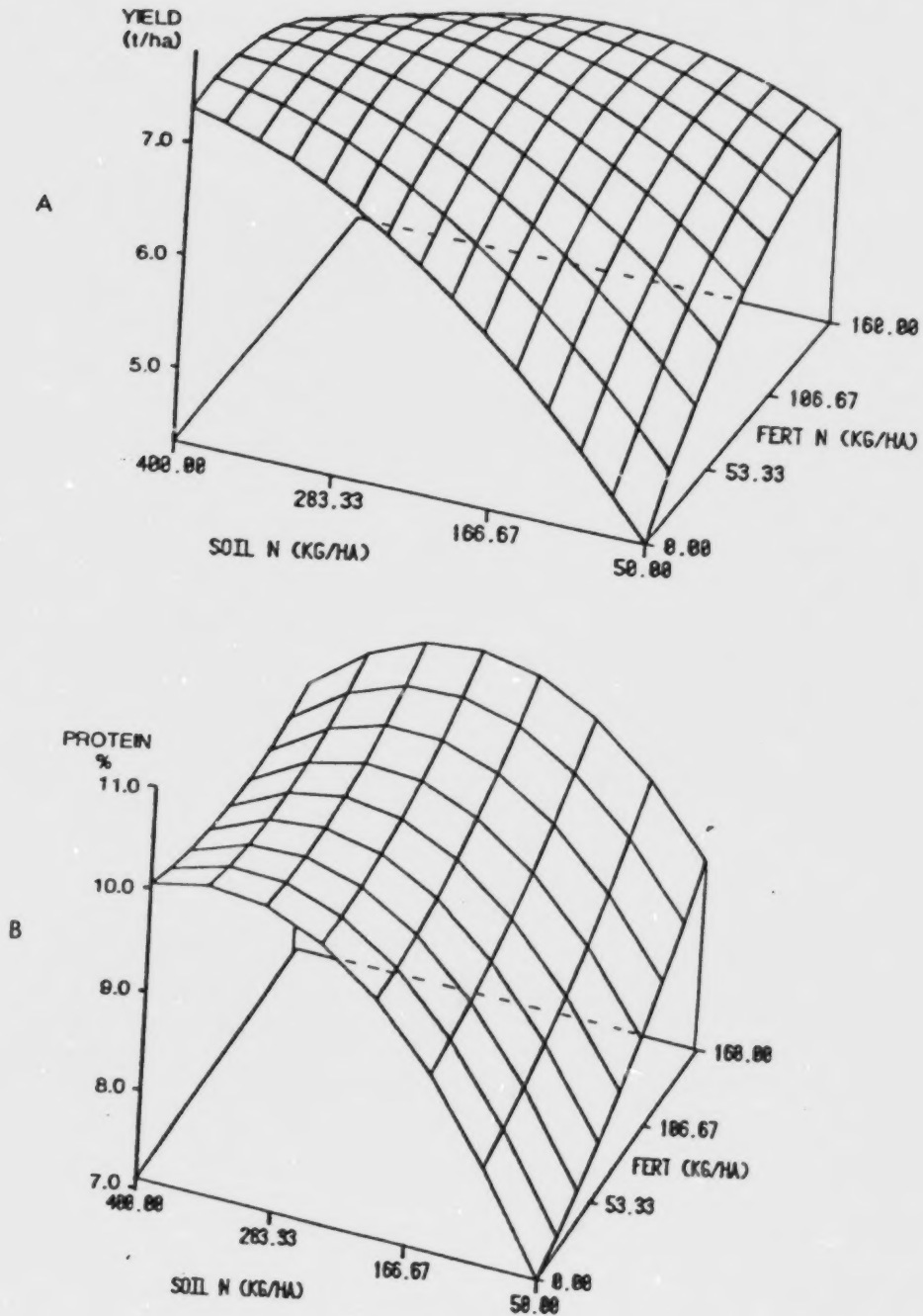


Figure 7. A- yield and B - protein content under different soil nitrate and fertilizer nitrogen under an optimum irrigation regime. (Bole, 1985. Personal Communication)

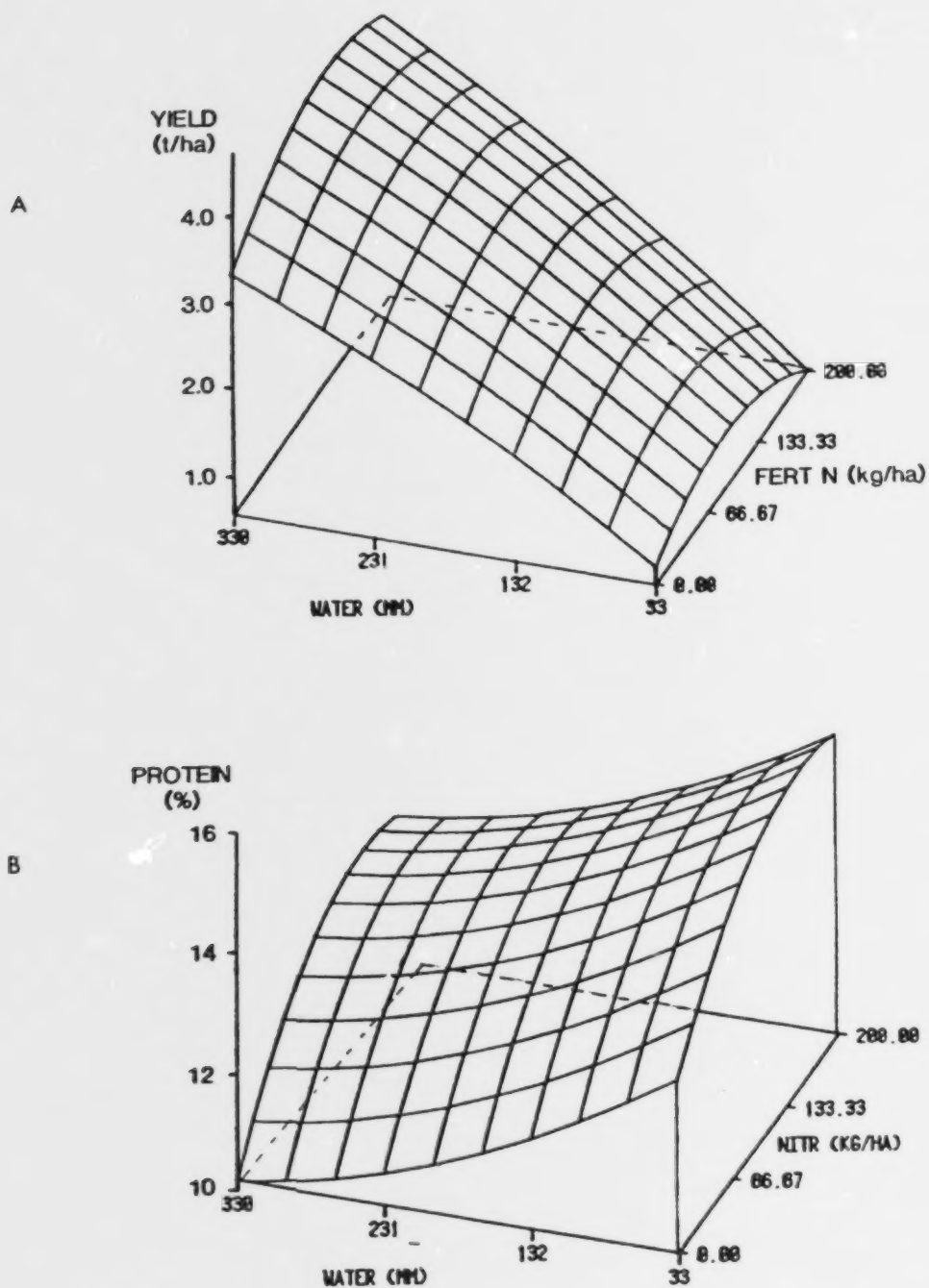


Figure 8. A - yield and B - protein content at varying water applied and fertilizer nitrogen. (Bole, 1985. Personal Communication).

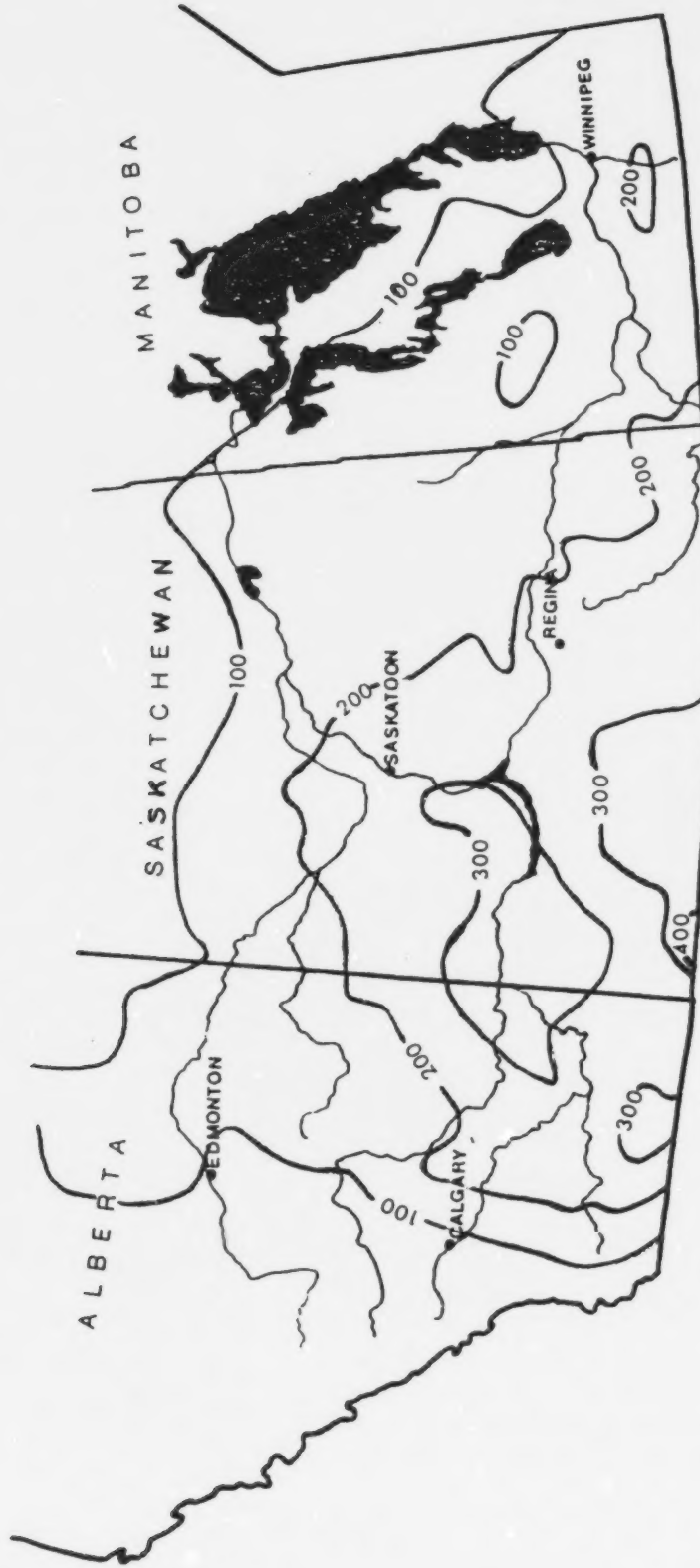


Figure 9. Average soil water deficit (mm) (Potential evapotranspiration - precipitation - 100) for the Prairie Provinces. (Redrawn from Agroclimatic Atlas Canada, Agrometeorology Section, Land Resources Research Institute, Ottawa.)

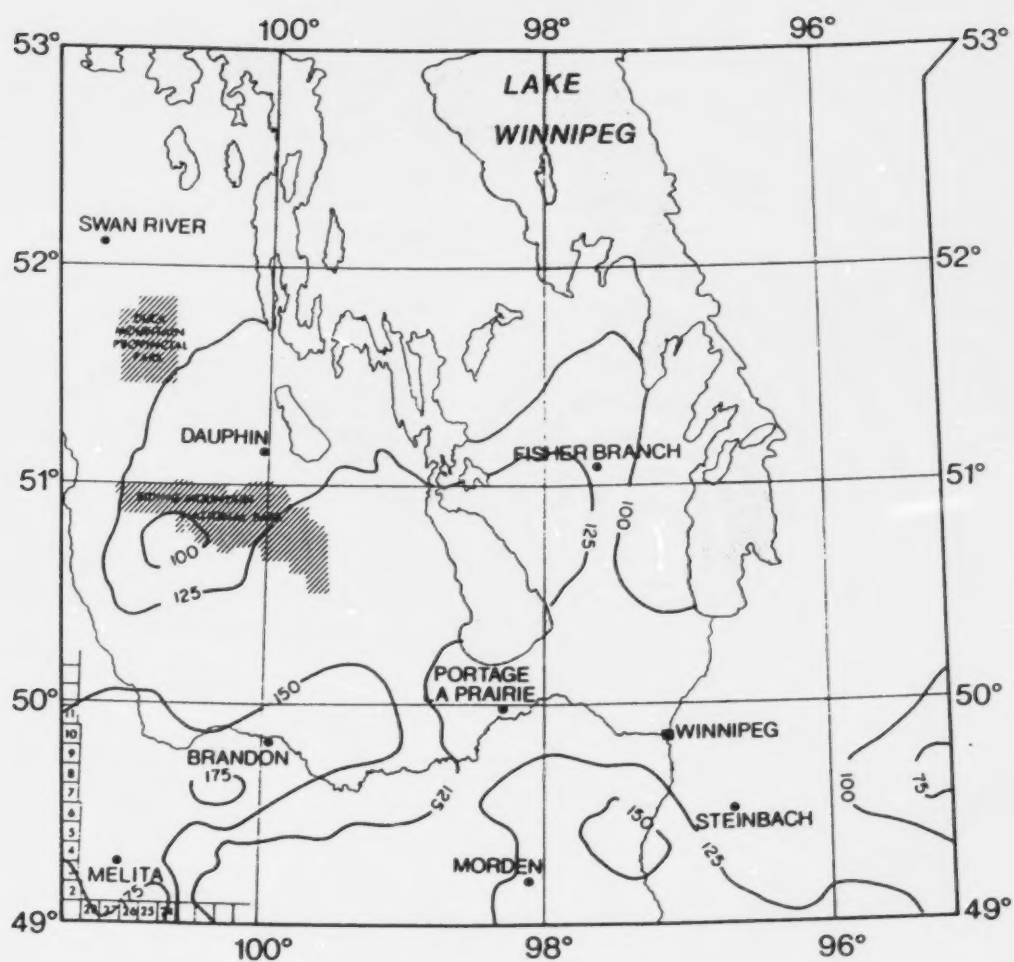


Figure 10. Average irrigation requirement (mm) to ensure maximum production of the second cut of alfalfa in Manitoba. (Dunlop and Shaykewich, 1984)

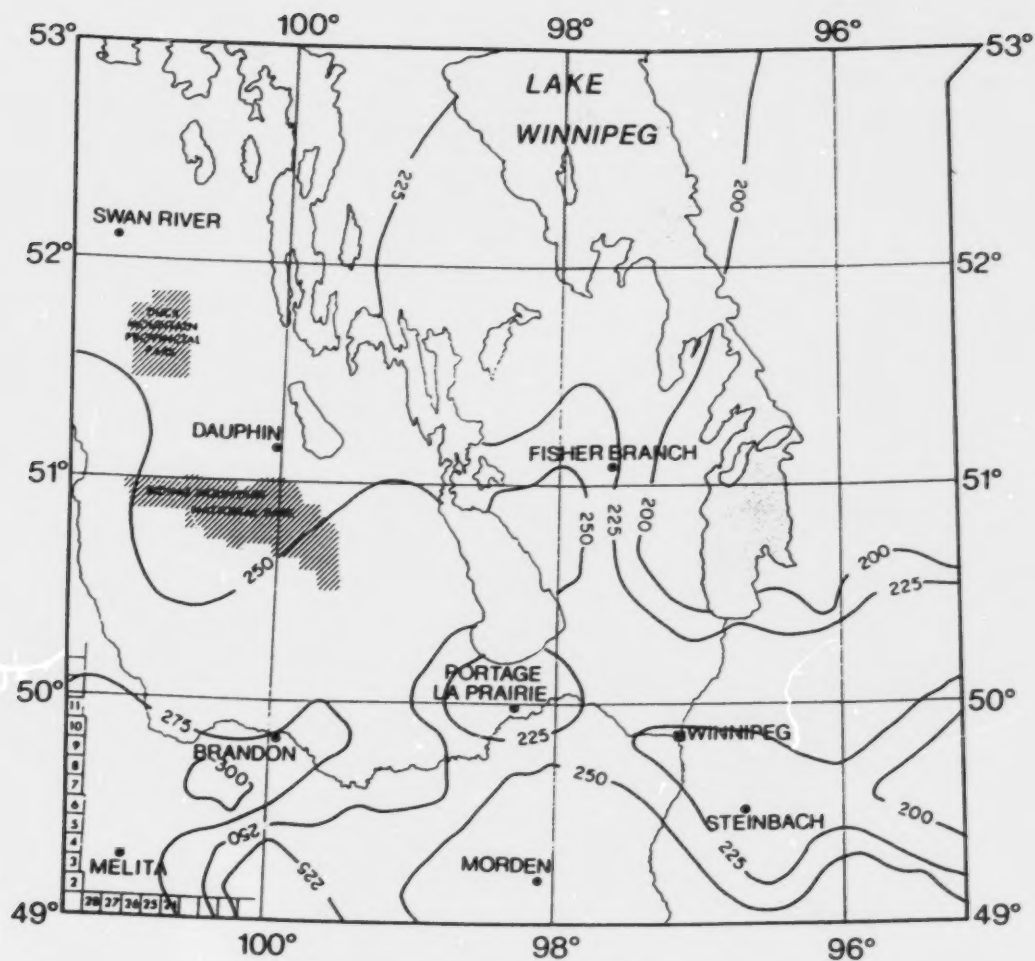


Figure 11. Irrigation requirement (mm) at the 10% risk to ensure maximum production of the second cut of alfalfa in Manitoba.
(Dunlop and Shaykewich, 1984)

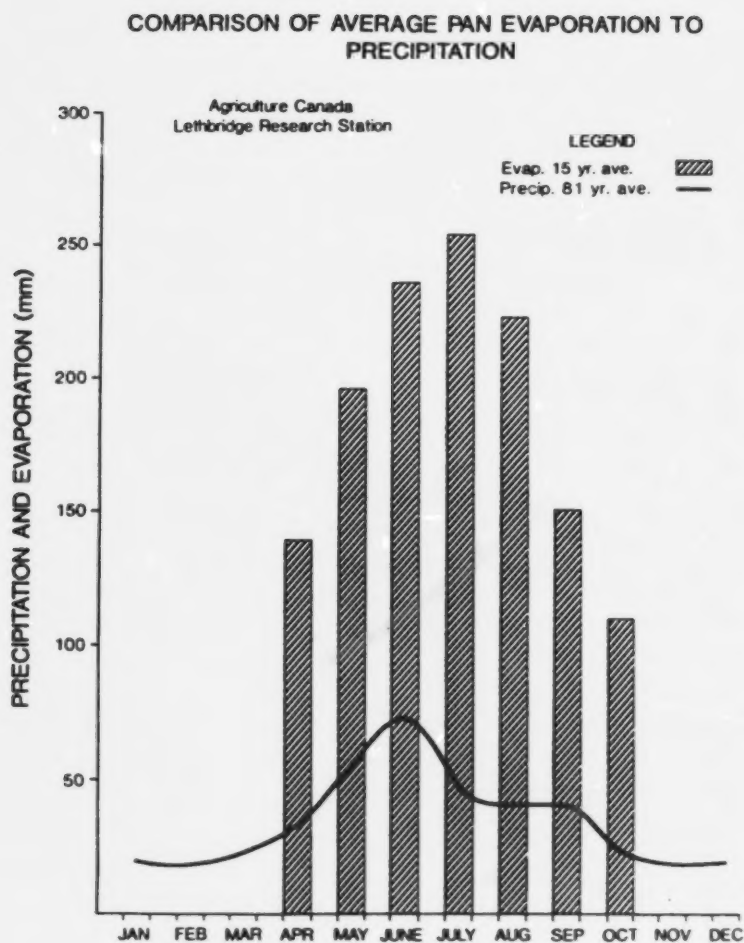


Figure 12. Comparison of average pan evaporation to precipitation at Lethbridge, Alberta.

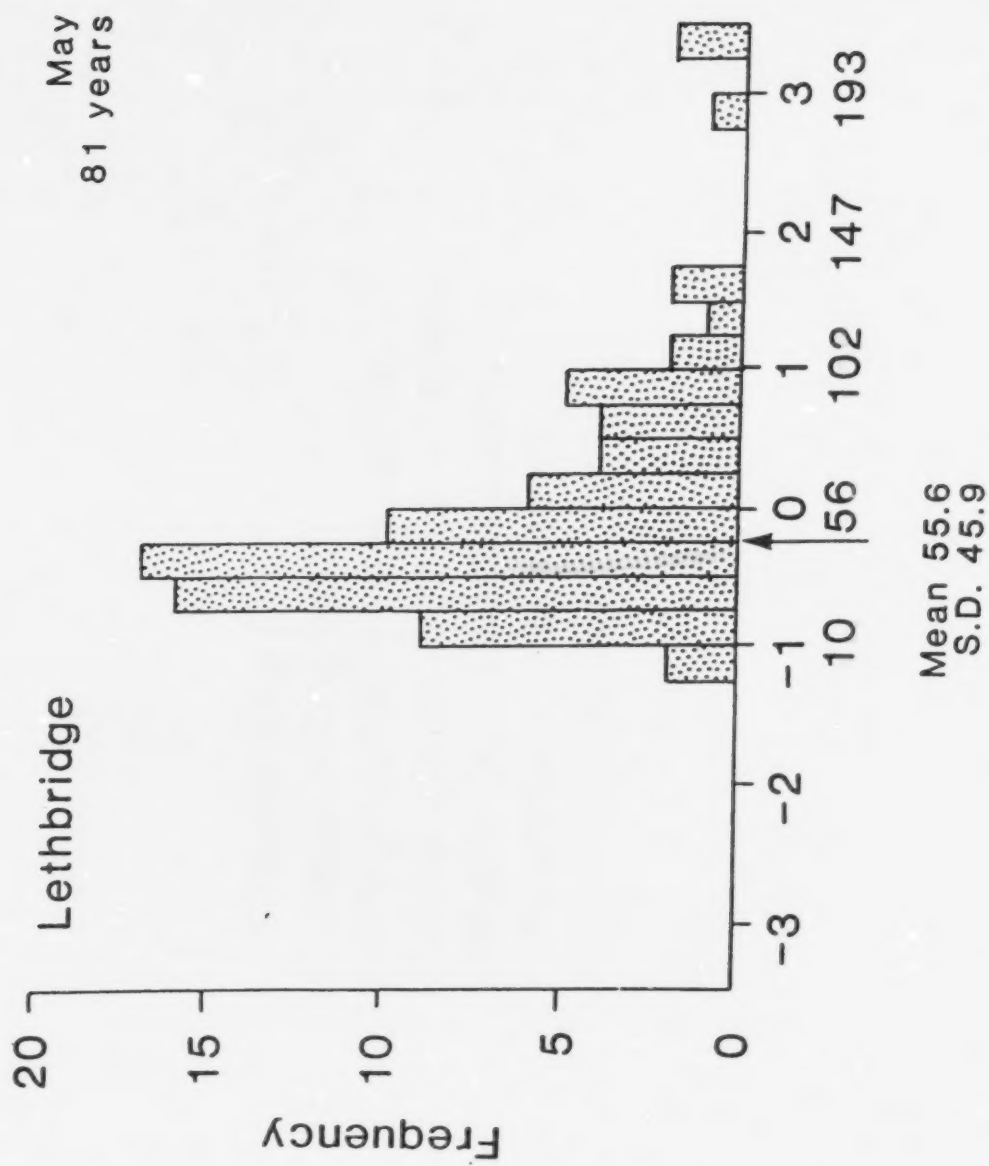


Figure 13. Frequency histogram for May precipitation (mm) at Lethbridge.

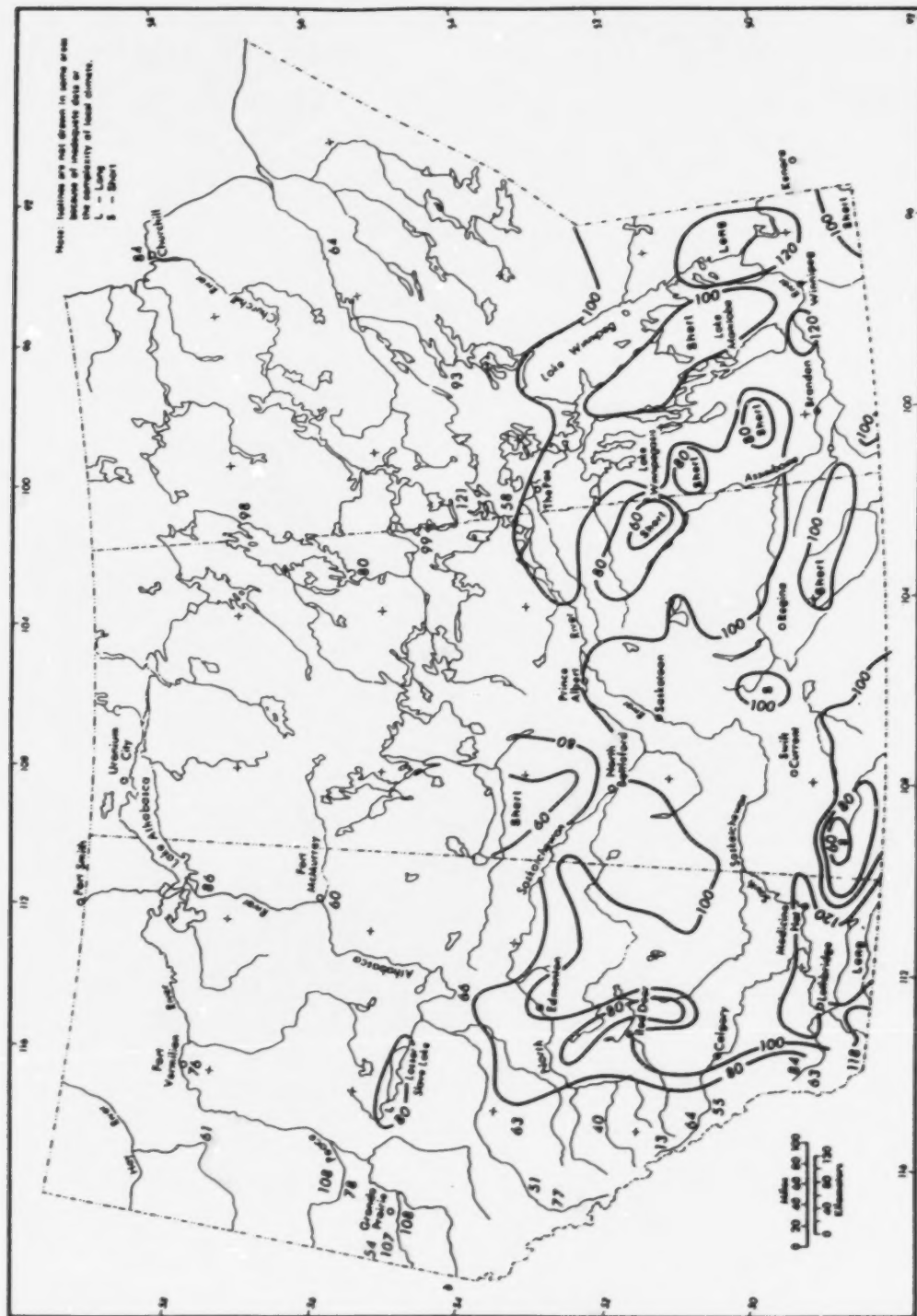


Figure 14. Average frost free periods (days) of the Prairie Provinces (Longley, 1972).

AVERAGE NUMBER OF CORN HEAT UNITS RECEIVED

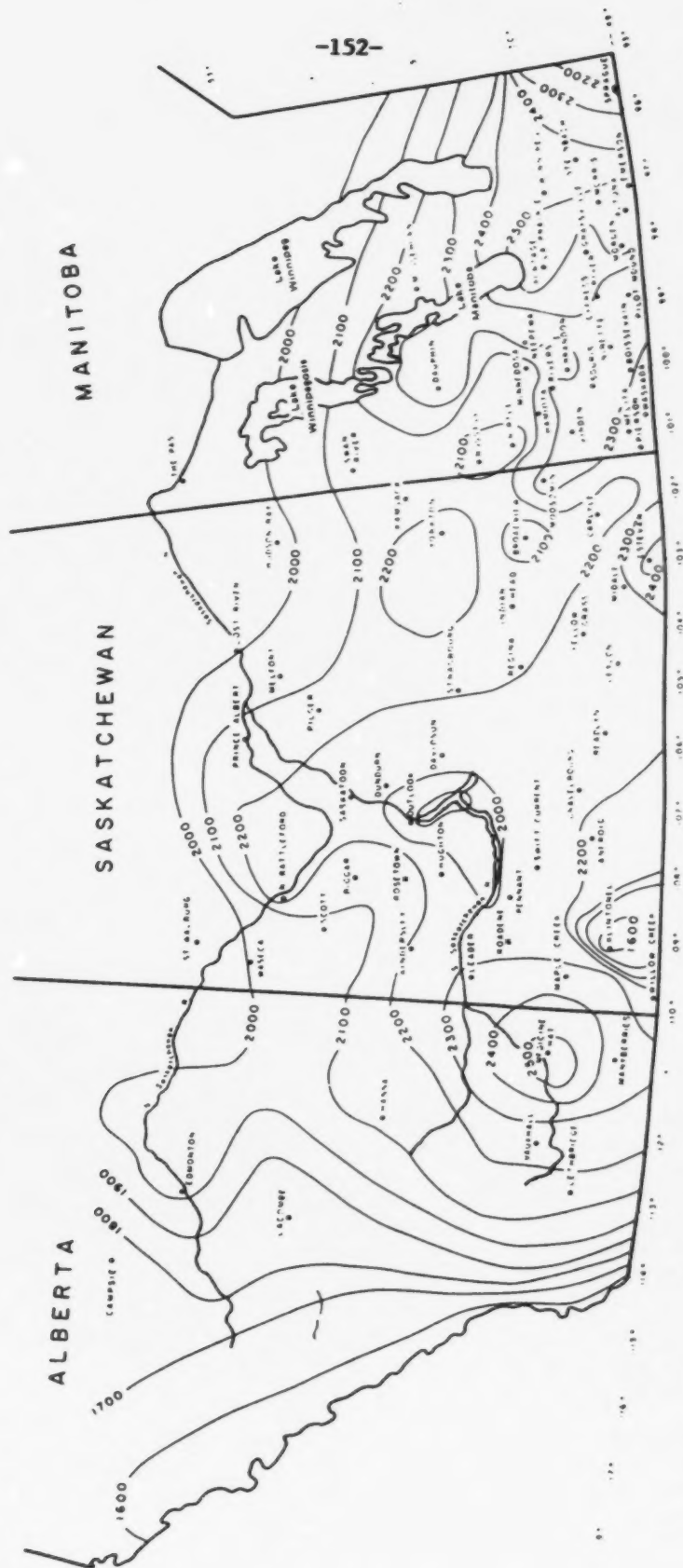
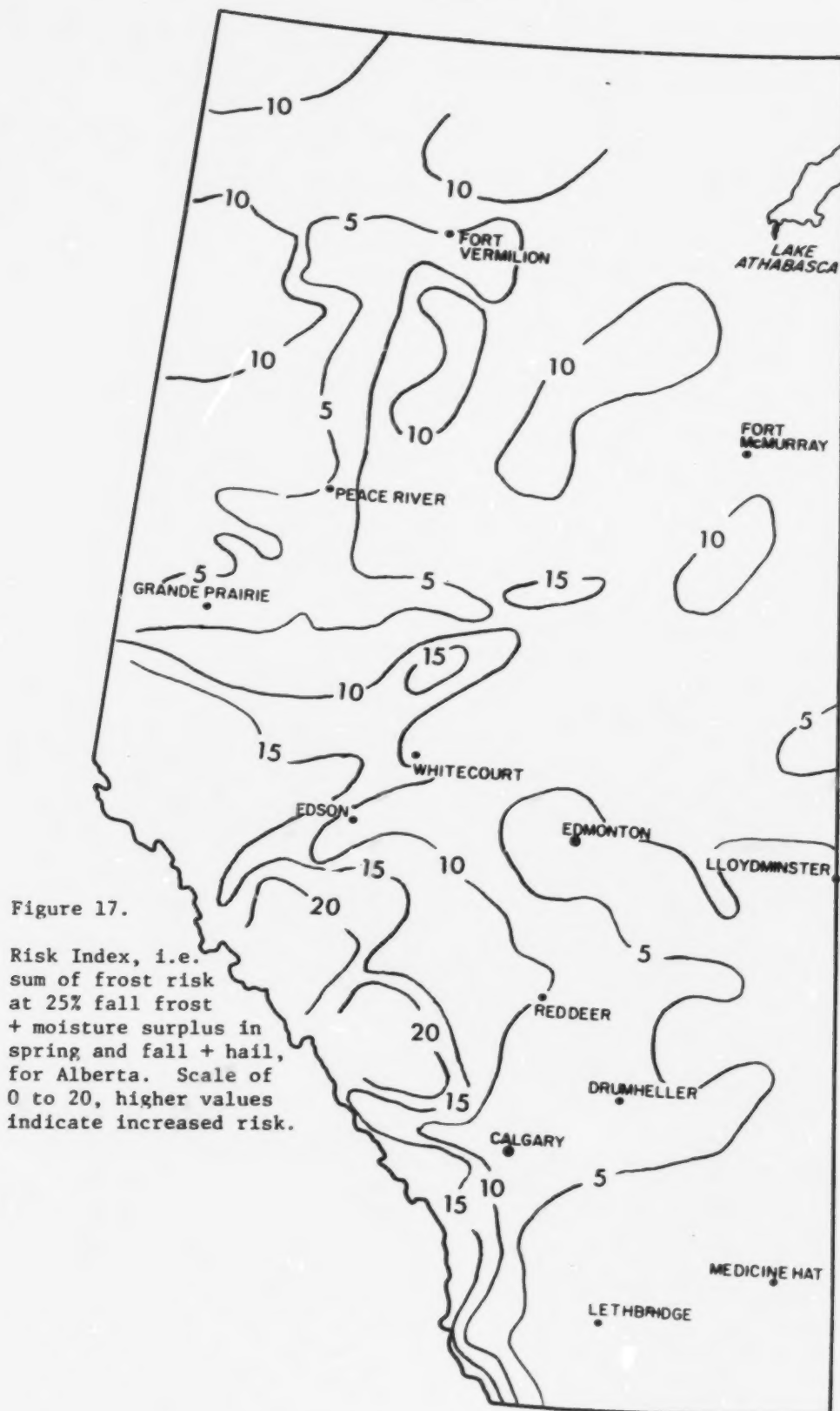
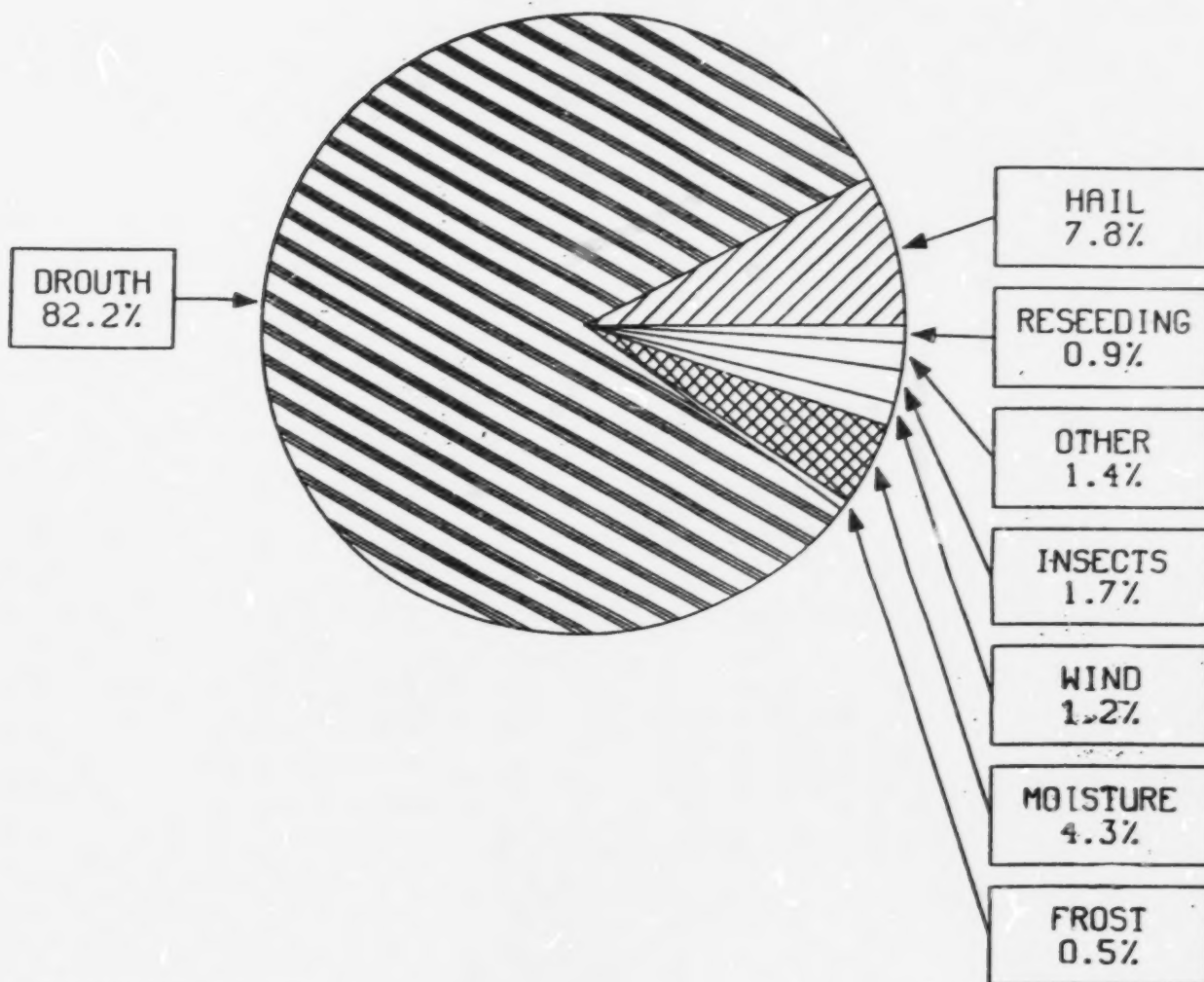


Figure 16. Average annual corn heat unit accumulation on the prairies. (Major et al., 1976)



ALBERTA HAIL AND CROP INSURANCE CORPORATION
LOSS DISTRIBUTION BY TYPE OF CLAIM
1984 CROP YEAR



PROVINCIAL TOTAL
VALUE OF LOSSES IS \$ 168,359,124
LOSSES BELOW 0.2% ADDED TO OTHERS CATEGORY

Figure 18. Causes of crop losses in Alberta in 1984.

FACTORS AFFECTING
ON FARM IRRIGATION EFFICIENCIES

Prepared by: R. D. Monaghan, Irrigation Specialist
Irrigation Branch
Alberta Agriculture
Lethbridge, Alberta

A. E. Pungor, Head
Irrigation Branch
Alberta Agriculture
Lethbridge, Alberta

February 1985

FACTORS AFFECTING ON FARM IRRIGATION EFFICIENCIES

R. D. Monaghan₁ & A. E. Pungor₂

Abstract

Irrigation Efficiencies are of growing concern in Alberta. This paper defines the on farm efficiencies for both surface and sprinkler methods. The report reviews potential losses and identifies where progress has been and should be made. The improvement of Farm Water Application Efficiencies from 1978 to 1984 is presented.

* * *

The South Saskatchewan River Basin Report published in July, 1984, indicated that 96% of the water consumption in the river basin is used for irrigation. There is an increased demand for this valuable resource in both Alberta and Saskatchewan.

Approximately 1.35 million acres are presently being irrigated throughout Alberta. Future expansion could bring that figure to 1.5 million acres by 1990. In addition to the agricultural need the demands for municipal and industrial water are also increasing. Water quality is another growing concern with the use of water for pollution dilution.

The competition for water and the desire to make the best use of the available resource have led to an increased awareness of Irrigation Efficiencies. The purpose of this paper is to outline practices and efficiencies at the farm scale.

The term "Irrigation Efficiency" is used very freely and most of the time is misunderstood. Therefore, it is important that we define it's meaning before extensive use.

1. R. D. Monaghan, P. Eng., IRRIGATION BRANCH, ALBERTA AGRICULTURE.
2. A. E. Pungor, Head, IRRIGATION BRANCH, ALBERTA AGRICULTURE.

Irrigation Efficiency is a general term used to define water losses during storage, diversion and application. In Alberta, our main concern is with the efficiencies that affect us from river diversion to field application. These are the water conveyance efficiency and the farm water application efficiency.

In general, the Irrigation Districts critical concern is the Conveyance efficiency. It is defined:

$$\text{Water Conveyance Efficiency} = \frac{\text{water delivered}}{\text{water diverted}} \times 100$$

During conveyance, water is lost because of:

- a) evaporation from free surface;
- b) seepage through canal wall of pipe joints;
- c) use by water weeds.

Through the Irrigation Capital Works Program and with the help of the Heritage Trust Fund, districts are taking steps to improve their efficiencies. Upgraded earthen canals, lined canals and pipelines are being constructed in order to reduce seepage and other sources of water loss.

The farmers primary concern is the Farm Water Application Efficiency. It is defined:

$$\text{Farm Water Application Efficiency} = \frac{\text{water stored for plant use}}{\text{water delivered to farm}} \times 100$$

During application on the farm, water is lost because of:

- a) evaporation from free surface and from sprinkler trajectory
- b) deep percolation (over-application)
- c) seepage
- d) field runoff
- e) overflow from pumping point
- f) equipment maintenance

Since our branch deals with the farming population on a daily basis, this paper will concentrate on Irrigation Efficiencies which directly affect the farmer, namely, Farm Water Application Efficiency.

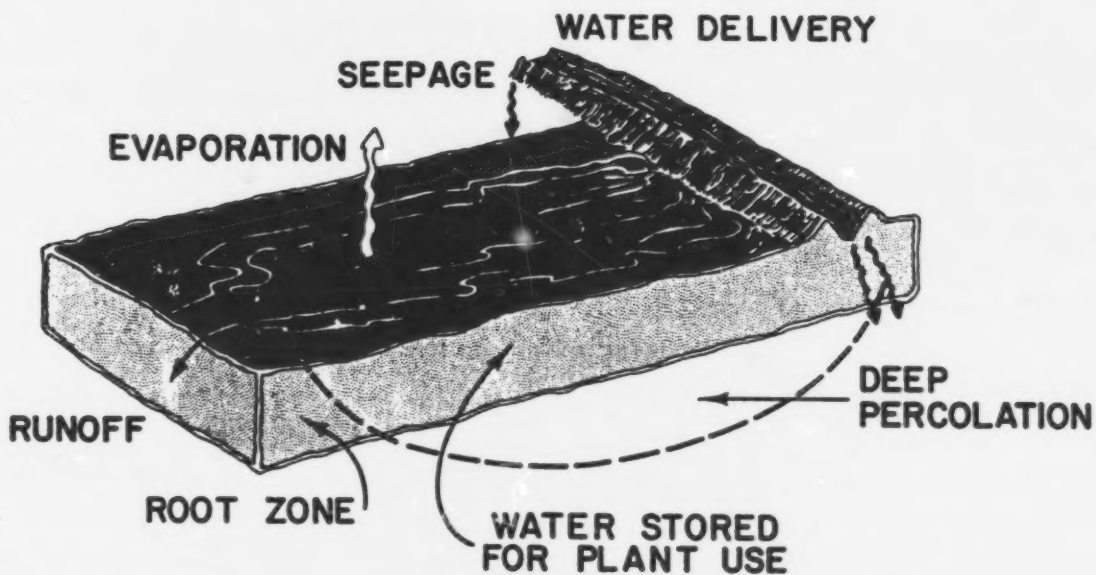
Irrigation system (gravity or overhead) may or may not be well designed and properly used. Accordingly, farm efficiency figures will move up and down on the scale. Actual efficiencies may fluctuate during a given day since the operation of an irrigation farm can influence them more than any other single factor.

While losses will occur with any system, they can and should be limited wherever possible. Good farm water application efficiency does not necessarily imply good irrigation practices. Poorly timed irrigation may be very efficient in terms of storing water for plant use, but will not be sufficiently useful for plant growth. The term Farm Water Application Efficiency should not be confused with other terms often used such as uniformity (equipment performance) or plant use efficiency (plant performance).

Surface irrigation accounts for 24% of Alberta's irrigation. Losses will include seepage, deep percolation, runoff and evaporation (Figure 1).

Poor irrigation practices in the past have given gravity methods a bad reputation. Excess irrigation was attributed with increasing salinity problems. Deep percolation and runoff losses can be controlled through proper water management. A well designed system correctly operated will minimize these as well as seepage losses.

Current practices to improve efficiencies include controlling stream size, length of run and duration of irrigation (opportunity time). Methods such as border dykes and control structures such as gated pipes control the movement of water and reduce seepage losses.



WATER APPLICATION EFFICIENCY (GRAVITY)

EFFECT OF FURROW LENGTH ON IRRIGATION EFFICIENCY



RUN TOO LONG

The good farm managers will be able to make further improvements by employing new technology. Currently being investigated are advancements in automation and surge irrigation.

Sprinkler systems are being used on roughly 76% of Alberta's irrigation farms. Side wheel roll systems are still the primary method for sprinkler irrigation accounting for 44% of Alberta's irrigation. (Source: IRRINV, Alberta Agriculture.)

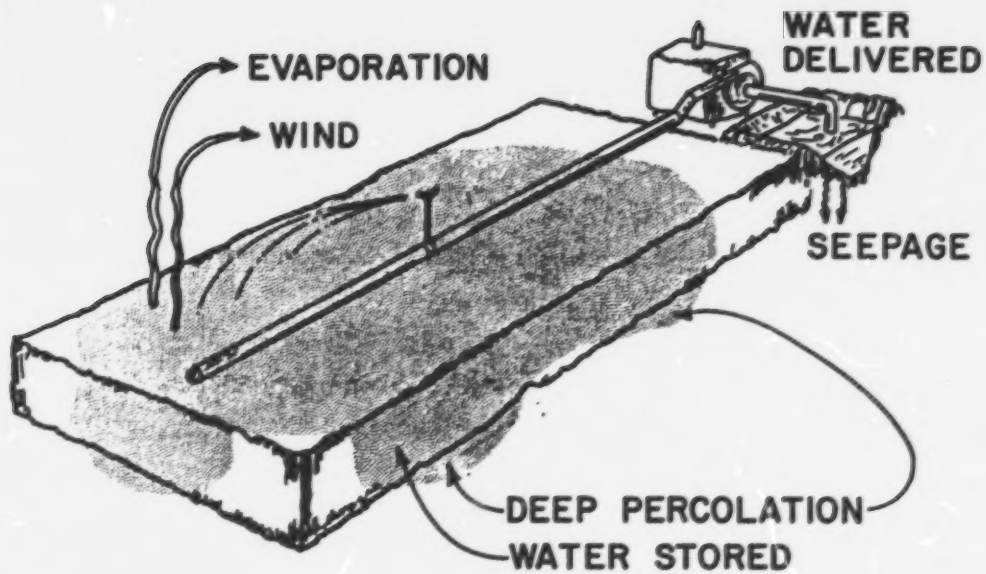
Typical side roll losses occur during set changes, runoff on steep slopes and deep percolation due to excessive operating pressures and duration of sets (Figure 2). The pumpsite can also have problems with seepage and overflow from the pumping point if too much water is being delivered.

While losses always exist, the dry summer of 1984 highlighted system problems. Poor wetting patterns were identified during an aerial inspection in early August. Localized runoff problems were also identified for both wheels and pivots.

Some systems had spot pressure readings taken. Of these, 50% were operating below pressure and 20% above pressure while only 30% of the nozzles were within the recommended operating range. (Source: 1984 Study, Dave Monaghan.)

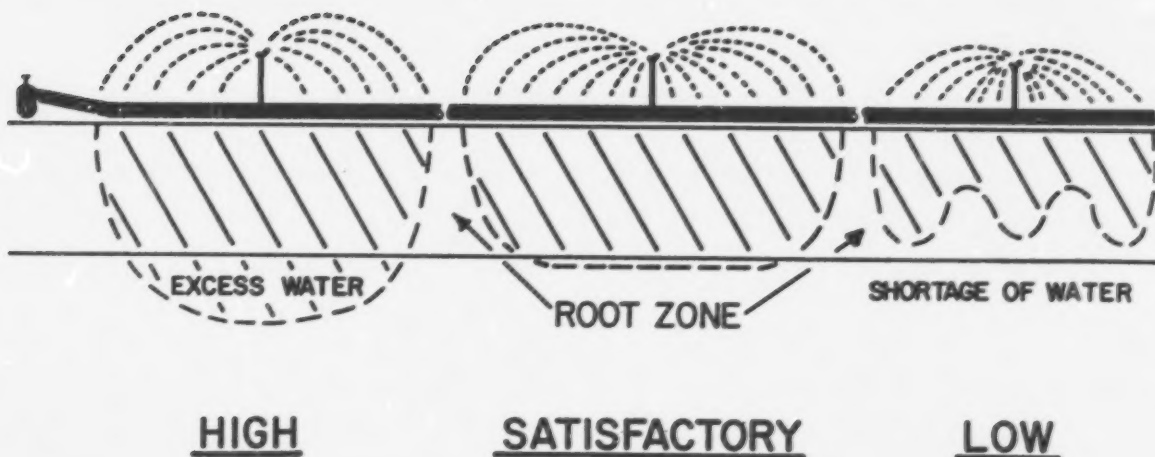
Sprinkler systems have traditionally been thought to be more efficient than surface systems. Therefore, while improvements have been made it has been a slower process to obtain results.

The number of center pivots in Alberta continues to increase and currently accounts for 32% of the systems. The water losses for pivots is similar to that of side wheel rolls.



WATER APPLICATION EFFICIENCY (SPRINKLER)

EFFECT OF VARIOUS PRESSURES



A major factor influencing the efficiency of pivots is their operating speed. Often farmers having problems maintaining adequate soil moisture conditions will speed up the machine in order to be able to cover the field more quickly and apply more water. Unfortunately, operating the pivots faster simply reduces the application efficiency and the net moisture applied since you will have approximately the same evaporative losses whether you apply 15 mm or 50 mm. The pivots should be slowed down as much as possible without causing runoff in order to reduce needless evaporation losses.

Actual Farm Water Application Efficiency figures for an area or irrigation district are impossible to obtain because it relates to individual systems, methods and operators. In other words, any method at any given day could have different efficiencies.

In Alberta the efficiencies shown in Table 1 are those used as an average achieved for each method of currently practiced irrigation.

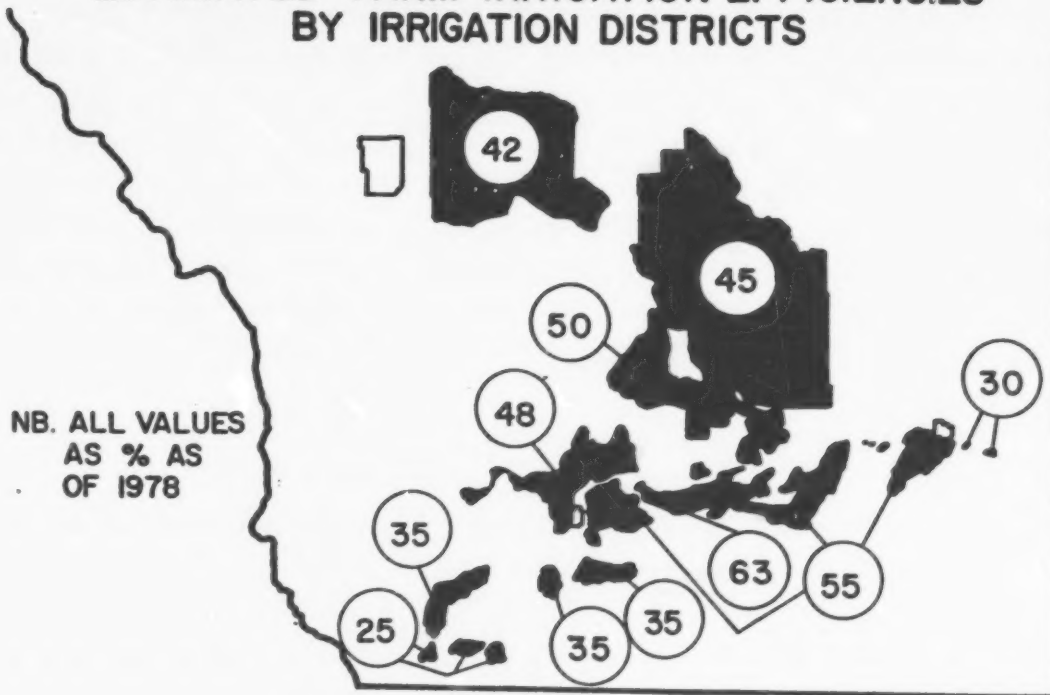
Methods of Irrigation

Trickle System	85%
Border Dykes	70%
Border Ditches	55%
Contour Ditches	24%
Side Roll Sprinkler	70%
Center Pivot Sprinkler	75%
Hand Move Sprinkler	70%
Furrow & Corrugations	60%

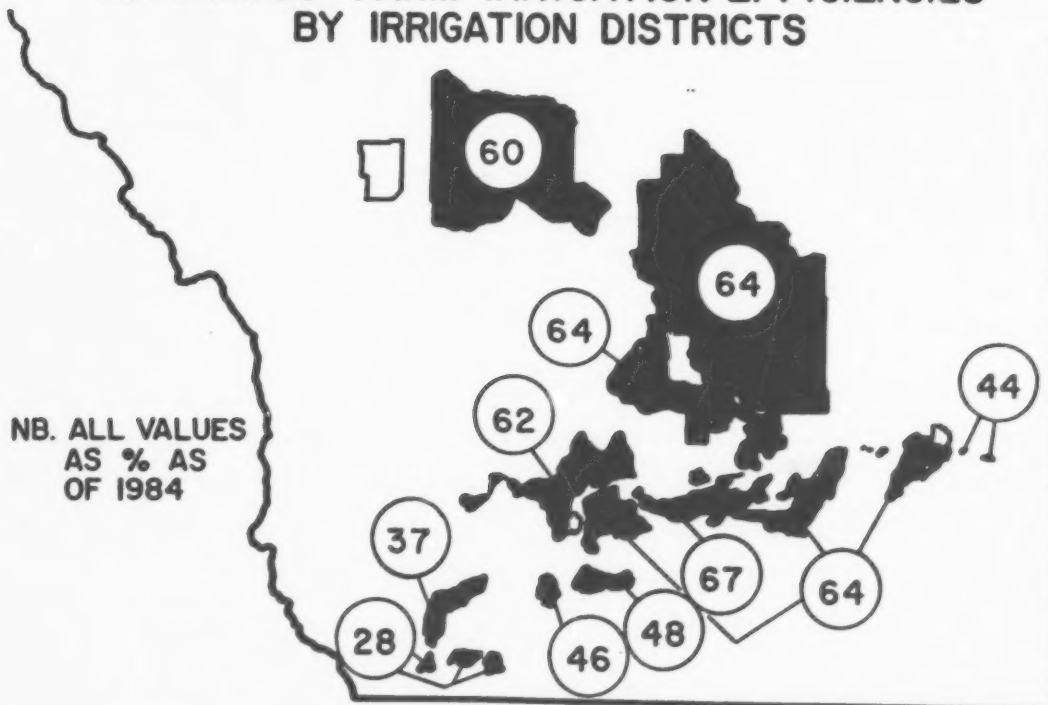
In 1977-78, during the Oldman River Management Study, we found a great deal of difficulty in establishing these numbers. Attached is a map (1978) (Figure 3) which provides averages for irrigation districts related to irrigation methods used. This data is based on some research, but mostly on experience and inventory findings.

FIGURE 3

ESTIMATED FARM IRRIGATION EFFICIENCIES BY IRRIGATION DISTRICTS



ESTIMATED FARM IRRIGATION EFFICIENCIES BY IRRIGATION DISTRICTS



The second map is a current (1984) review of efficiency figures for each irrigation district arrived at in a similar manner as the previous one and it suggests notable on farm efficiency increases. These increases during the past six to seven years are attributed to the following reasons:

- 1) Irrigation Branch programs and personnel (awareness, assistance, technology transfer).
- 2) Irrigation methods used by farmers (technology).
- 3) Improved irrigation system design by dealers, manufacturers.
- 4) Upgraded irrigation system maintenance by farmers.
- 5) Improved irrigation system operation and management practices by farmers, including drainage.
- 6) Improved water delivery and control by farmers and districts.
- 7) Irrigation scheduling (rotation, shortage, drought, etc.).

There is a strong relationship between Conveyance or Water Delivery Efficiency and Farm Water Application Efficiency. An improved Farm Water Application Efficiency may adversely affect Conveyance Efficiency unless the district management realizes the effect and attend to it by making adjustments. On the other hand, district management practices may alter water supply delivery, availability and drainage, which in turn will affect the farmers capability to practice efficient water use.

During water application (irrigation) an operator will encounter different losses due to a number of factors. By controlling these losses through better management practices, the Farm Water Application Efficiency will increase. Conscientious management will not only increase efficiency but will eliminate fluctuations of system operations and make more effective use of the irrigation water.

Optimizing Wheat

Brad Brown

Department of Plant, Soil and Entomological Sciences
SW Idaho Research and Extension Center
University of Idaho
Parma, Idaho 83660

Intensive Cereal Management

Maximum economic yields of irrigated wheat are essential for reducing per unit production costs, increasing financial returns to producers, and providing a stable, ample supply of wheat for world food needs. This presentation will focus on Intensive Cereal Management (ICM) and its role in maximizing economic wheat yields under irrigated conditions. I will assume that moisture is not a limiting factor to production.

My experience with agriculture in the Canadian prairies is limited. I can not tell you specifically the operations and practices necessary for maximum economic wheat yields in this region. I hope to leave with you a prescription or blueprint, to maximize economic yields, a prescription that others are using with some success in many areas of Europe as well as in North America.

The approach is similar to others in that it attempts to identify factors which limit production. The difference is that ICM examines not only single factors, i.e. planting dates, fertility, but interactions of several factors. Positive interactions have potential for markedly enhancing yields and lowering per unit production costs.

For example, consider three varieties of wheat (Stephens, Daws and Nugaines) treated similarly with three levels of N, (0, 100 and 200 lb/A). At 0 and 100 lb rates varieties did not differ in their response to N. Yields of varieties were the same and the yield of all varieties was increased 30%. But variety response was quite different at the highest N rate. Stephens yielded almost 30 bu/A more than Nugaines at the high N rate. That's about a \$60/A increased return resulting from appropriate variety selection and adequate N fertilization. The practical importance of this is that fertilizing for maximum yields of some varieties may be limiting the yields of more productive varieties. This variety and N interaction was measured at Parma in 1978 and is only one example of the interactions that are sought out in our cereal research. ICM uses these interactions, in fact depends on them, for boosting yields, lowering per unit production costs and increasing economic returns.

The study of interactions in itself is not new to Canadian cereal researchers. But, if they are like so many of us, we don't examine these potential interactions nearly as much as we should.

Significant short term advances in wheat yields are not likely to come from genetic improvement as we have plateaued in the yields of many

commodities. The study of these interactions may in fact offer more potential in the short term than a more basic approach to yield constraints.

The irrigated wheat producers in SW Idaho are not satisfied with 100 bu/A wheat, and haven't been for some time. The better producers are already averaging 120 bu or 140 bu/A. In 1983, there were three undocumented reports of 200 bu/A winter wheat in Canyon County alone. These yields were apparently obtained without extra costs associated with fungicides, insecticides or plant growth regulators.

There is a certain irony in this, too. Of the commodities that are included in the rotation with wheat, including mint, beans, potatoes, sugarbeets, onions, vegetable, flower and legume seeds, corn and alfalfa, only one receives less intensive management than wheat and that's alfalfa. Despite some of the greatest potential for wheat production in the world, our growers as a rule tend not to give it the attention it needs.

Constraints to Implementation of ICM

This brings us to some of the constraints to implementation of ICM. The increased operating costs inherent in increased fungicides, growth regulator and fertilizer applications discourages attempts to use them even on a trial basis. Growers are especially reluctant to experiment on a crop that at present is providing little if any economic return due to poor markets. Any yield increases are considered by some to be adding to the problem of surpluses.

Also, wheat is the least important crop in the rotation, and therefore receives the least intensive management because there are not the costs of production there are for the other commodities. Faced with the decision to spend time managing a potato crop involving production costs of \$1500-2000 per acre and a wheat crop involving only \$150-200 per acre, it is no wonder that wheat does not receive the attention it needs. Furthermore, the potential income is so much greater with the higher value commodities, (onions, potatoes, sugarbeets and seed crops) that the producer understandably spends his time on those commodities which have the greatest potential for economic return.

Canadian researchers can list the constraints to production better than I. It doesn't matter whether we speak of winter or spring wheat, the general principle is the same. Identify the easily recognized limiting factors, eliminate those and examine others that occur as production is increased. This means, in some cases, testing some very traditional cultural practices that are deeply entrenched among producers, i.e. planting dates, row spacing. We at times have met resistance to the evaluation of these time worn practices from members of our own research community. I can think of pathologists, accustomed to severe problems of soil borne diseases, suggesting in an area where good rotations eliminate the concern for these diseases, that late planting dates will be as effective as earlier plantings. In four of the last four years we have proved them wrong. Winter wheat yields have been reduced

from 5 to 20 percent by delaying the planting 30 days from mid October. Late plantings in November in SW Idaho have never been as productive as mid October plantings.

The Blueprint

Rotation - The approach of ICM to maximizing economic wheat yields begins very early with consideration for the rotation. Unfortunately, climatic and economic constraints sometimes dictate rotation limitations. But a diverse rotation will go a long way toward reducing the incidence and severity of soilborne diseases. In most cases, residual N remaining from the previous crop in a diverse rotation will reduce the need for fertilizer N on the wheat crop. If your producers are still planting wheat two, three and four years in a row, then alternative crops are sorely needed to break up that practice.

Variety - The importance of appropriate variety selection is pretty obvious to most. You may not have the option to plant as many varieties as are available to our growers from public and private plant breeders. To participate in government programs you may be limited to very few certified varieties.

Seed Quality - Seed quality is another important consideration. Most growers are acquainted with the advantages of certified seed. Nevertheless, a recent drill box survey in Idaho indicated as much as a third of the wheat drilled in 1984 was contaminated with wild oats. We can reduce yield limiting weed populations by using clean seed.

The sizing of seed can also be important. Research at Oregon State suggested that winter wheat yields were enhanced 3-5 bu/A by using seed sized larger than 6 1/2 or 7/64 inch. The gains came from more vigorous seedling growth. Seed treatment may also be necessary for added disease protection.

Seedbed Preparation - Seedbed preparation is apparently recognized by most producers here as being highly important or the most important farming operation under their control. Drilling into slightly firm seedbeds and packing the seed insures more rapid and uniform emergence as well as providing a more ideal environment for all seedlings. Important yield components are determined early in seedling development. The potential number of tillers as well as the potential number of seeds per head are determined prior to the fourth leaf stage. Maximizing economic wheat yields is not possible if the number of heads due to tillering or the seeds per head are limited early in the season. Some compensation will occur in increased seed size but it generally will not make up for reduction in the other components even if ideal conditions are encountered during the remainder of the season.

Planting Date - There are not many practices these days that will increase production that don't also add to production costs. An optimum planting date is the exception. For spring wheat the earlier the planting the better, as long as soil temperatures are high enough to enable seeds to germinate. Early planting insures wheat development during more optimum temperatures.

Tillering and grain fill are favored by cooler temperatures. Excessive heat during grain fill, though it may increase the rate of fill, generally reduces the duration of fill and filling is reduced. Early seeding helps avoid these higher temperatures. Optimum planting dates will differ by location and local authorities will know what is best for each area.

Seeding Depth - Optimum seeding depth will be governed by availability of moisture and variety selection. Semi-dwarf varieties have shorter coleoptiles and must not be planted as deep as other types as any crusting will reduce stands. The seeding depth should not be any deeper than necessary to insure adequate moisture for germination. Seeding deeper than necessary will place seed in cooler soil which will slow germination and emergence and can result in decreased seedling vigor. It may even be necessary to lightly irrigate after seeding to insure rapid and uniform emergence.

Seeding Rate - Seeding rates of 75 lb/A should be adequate if the planting is early and conditions are present for good rapid germination and emergence. Seeding rate will depend to some extent on the condition of the seedbed. Poor seedbeds may warrant increased seeding rates. Later plantings and reduced tillering may also warrant increased seeding rates. Optimum populations for spring wheat should be 12-20 plants per square feet. Fielder contains about 85,000 seeds per bushel. A 75 lb seeding rate (1 1/4 bushel), assuming 85% germination, will result in 20 plants per square foot which should be adequate under optimum conditions.

Row spacing I have alluded to previously. Suffice it to say that many areas are showing a response to narrower than conventional row spacings, row spacings as narrow as 3 and 4 inches. As we eliminate other factors which are limiting production we may find that narrower rows and more optimum spacing of wheat plants are necessary for maximum economic yields.

Seeding equipment available in the future is likely to be more varied and improved. Regardless of the type, the planter needs to insure good seed-soil contact, uniform planting depth, and accurate seeding rates.

Plant Nutrition - Adequate plant nutrition will be an integral part of higher economic yields. N will generally be the most limiting. The importance of N is due not only to its effect on yield but also to the adverse effects of high N on soft white wheat quality, i.e. high protein. Residual N from the previous crop and the N mineralized during wheat growth will reduce the need for fertilizer N. Therefore, it is important to soil test prior to planting to determine residual inorganic N as well as the N likely to be mineralized during wheat growth.

Soil should be tested for N prior to each wheat crop rather than every other year or longer. The N in the soil-plant system can be extremely transient and infrequent soil sampling is not sufficient to monitor its potential contribution to wheat. Sampling for N should extend to the effective rooting depth of the wheat.

Soil tests for inorganic N have been shown to be closely related to relative yields of cereals in the Pacific Northwest as well as the Canadian prairies. Soil test calibration studies conducted under Canadian prairie conditions should be used for determining N recommendations.

Few areas in the country have routine soil tests for determining the potential contribution of mineralizable N to the N needs of wheat. Yet, most everyone acknowledges that this contribution can be appreciable. These soil tests need to be developed for routine testing and this contribution of N quantified in order to more accurately determine fertilizer N requirements. Mineralizable N in diversified cropping systems can differ markedly depending on previous cropping and cultural practices. The importance of accounting for mineralizable N will become greater as irrigation brings greater diversification to rotations.

The most effective timing of N application will depend on many factors including soil type, precipitation, other climatic conditions and class of wheat grown. In low rainfall areas we have not shown yield advantages by splitting the N application between preplant and vegetative stages. Grain yield is not always affected, but late season applications at heading or flowering have increased grain protein.

Late fall applied N can be as effective as spring preplant N assuming an ammoniac source of N is adequately incorporated. Fall applications may in fact be more economic. If fall applications enable a cheaper N material such as anhydrous ammonia to be used, fertilizer costs can be reduced. Occasionally fertilizer dealer stocks will be high enough in the fall that discounts will be provided for fall fertilizing. If so, again, some fertilizer costs can be reduced.

Some drills are equipped to apply fertilizer with the seed. This is a convenient means of supplying the early portion of the crop's requirement but care should be taken not to apply amounts that can affect germination and seedling damage. The maximum amounts to be drilled with the seed should not exceed 25 lb/A of urea N and should be used only on loam or heavier textured soils.

Phosphorus (P) is not generally needed as much as N. Soil testing for P will indicate residual fertility. Values of 10-15 ppm are generally deficient. The availability of P is tied closely to soil temperatures, soil moisture, and root diseases. Under the cool soil temperatures encountered in the Canadian prairies, growth response to P applications can frequently be shown even though soil test P levels are high. The most convenient and effective P application for cereals is often the placement of P with the seed during the drilling operation. This saves the costs of the application, and positions the P where it can be used by the developing seedling. Rates of P can, in some cases, be reduced with this method.

Potassium (K) deficiencies are generally not as prevalent as those of N or even P. Soil testing for K can identify K needs. Responses to fertilizer KCl

have at times been reported on soils testing relatively high in K. These responses in many areas such as Montana and South Dakota have been attributed to the presence of the chloride (Cl) ion rather than the K ion. The Cl appears to have some influence on suppression of various plant diseases. The exact mechanism or reason is poorly understood, consequently it is difficult to predict when or where the responses will occur. In general the response is greatest under conditions where root diseases such as Take-all (*Guamanomyces graminis*) occur, i.e. two and three year wheat rotations.

The most effective placement of K is with the seed assuming high K rates are avoided. Under most conditions the rate should not exceed 175 lb/A. As with P, cool soil temperatures and poor mobility in the soil can limit the availability to a developing root system.

Plant Protection - Weed control, particularly during early wheat development is critical for maximum economic yields. Weed competition during early wheat development is generally the most damaging. Competition at this point affects yield components of tillering and seeds per head.

Weed control does not just involve cultural practices that begin shortly before planting or during the growth of the crop. The most effective program is one which includes a previous commitment to control weeds in crops preceding the wheat planting.

Appropriate timing of the herbicide application is important. Following label recommendations is critical for maximizing weed control and reducing the effect on the wheat crop.

As yields increase as a result of more intensive cereal management, you can expect more extensive crop canopies. This increased canopy could easily foster a more humid and favorable microenvironment for insects and foliar diseases. This points to the need for careful scouting of fields and if need be the labeled application of appropriate insecticides and fungicides. Indiscriminate spraying should be avoided because it is not only costly but resistance can be built up in the target pest population.

Plant Growth Regulators - Though varieties of soft white spring wheat currently available are semi-dwarf they are still susceptible to lodging under high N conditions and the combination of rain and wind. In the Alberta grower survey of 1984 lodging was rated very low as a problem by 93% of the producers. I have mixed feelings about this. On the one hand lodging is a problem which robs us of the grain that's produced or reduces production outright. On the other hand many successful Idaho producers aren't happy unless some lodging, hopefully a small amount, is present. It shows then at least N was adequate. The Alberta survey suggests to me that N added by most producers is not sufficient for consistent maximum economic yields, but there is little if any data to show this. Plant growth regulators used to control plant height and strengthen wheat stems have proven beneficial in some areas. Winter wheat yields have been increased with these growth regulators at higher N rates. We need more information on the use of these products on both winter and spring wheat.

Summary

Finally, more intensive cereal management will undoubtedly call for increased production inputs. Some of these will be necessary for maximizing economic wheat yields. Nevertheless, each practice needs to be carefully examined for its appropriateness under your conditions. If insect pests have never been an economic problem in your respective areas and they prove not to be when and if yields are enhanced, then obviously it will not be in your economic best interest to use insecticides. Or, if there are constraints to yield above and beyond your control such as severe soil or climatic limitations, there is little likelihood that the increased inputs will benefit you.

In conclusion, what I have presented to you is a prescription that can guide your research and efforts to maximize economic wheat yields. I have made the presentation at the risk of telling you what you already know. I encourage you to increasingly look for those interactions which will boost economic yields. Do not be dissuaded from the evaluation of popular or conventional practices or by the misgivings of your colleagues.

Thank you for the opportunity to address you. Best wishes on maximizing economic wheat yields.

FOURTH ANNUAL
WESTERN PROVINCIAL CONFERENCE
RATIONALIZATION OF WATER AND SOIL RESEARCH AND MANAGEMENT
"IRRIGATION ON THE PRAIRIES"

November 25 - 27, 1985, Saskatoon

OPTIMIZING COMMERCIAL VEGETABLES

Presented by: Dr. M.K. Pritchard,
Department of Plant Science,
University of Manitoba,
Winnipeg, Manitoba R3T 2N2

The production of potatoes and vegetables on the Prairies, though limited due to size of the market are important to the western economy. The farm gate value of potatoes and the four major vegetable crops including onions, carrots, cabbage, and rutabagas is approximately \$66.5 M. Processing, particularly of potatoes, substantially inflates this value. Despite the relatively small hectareage of production, proper fertility programs are perhaps more important in potatoes and vegetables than in agronomic crops because of the very high value per hectare (Table 1). Besides yield considerations, potato and vegetable producers must be concerned with the effect of soil fertility on fresh market quality and appearance, quality requirements for processing, and the influence of fertilizers on storage life. A large percentage of the potatoes and all vegetables grown on the Prairies are produced under irrigation. Since most of these crops are grown on the light to medium texture soils, fertility management, particularly of nitrogen, becomes critical under irrigation. Cropping practices and growth characteristics of potatoes and vegetables have implications with respect to optimizing fertilizer efficiency and fertility management. Unfortunately, many of the fertilizer recommendations are the result of testing done outside the Prairie region.

Potatoes and the vegetable crops being planted as row crops make optimum use of nitrogen and phosphorus when at least a portion of the fertilizer is applied as a band at planting. Some growers however are still broadcasting the majority of their fertilizer. Potatoes and vegetables are shallow rooted crops compared to agronomic crops. Potatoes root to a depth of about 0.8 m (Figure 1), carrots and rutabagas to about 0.9 m, and onions and cabbage to about 0.6 m. Because irrigation can readily leach nitrogen from the rooting zone especially in lighter soils, a mid-season application of fertilizer is recommended for crops such as onions in an Alberta recommendation. Additional nitrogen one month after establishment is also recommended in cabbage. However, despite a high nitrogen requirement by potatoes, most producers are applying all the nitrogen at seeding. Of particular concern is the detrimental effect of nitrogen applied in mid-season on the color of processed potatoes. Potatoes for fresh market would likely benefit from a mid-season application of nitrogen. A report out of Washington

in 1983 stated potato growers there are overfertilizing by 30% and suggested one-third to one-half of the nitrogen be applied before or at planting and the balance later in the season. The increasing use of fertigation on the Prairies should result in more efficient nitrogen fertilizer use by providing a more uniform level throughout the growing season.

Soil sampling in October of 1982 found several vegetable fields in Manitoba to have nitrogen levels in excess of 200 kg/ha in the top 60 cm. Growers are now becoming aware of overuse of fertilizers. Inclusion of deeper rooted crops such as cereals, canola, or alfalfa in rotations aids in removing some of this residual nitrogen which accumulates below the root zone of potatoes and vegetable crops. Ground water quality also becomes of concern with accumulations of such high levels of soil nitrates.

Quality aspects and storage life of potatoes and vegetables both for fresh market and processing must be considered when developing a fertilizer program. Excessive nitrogen can cause growth cracking and increased hollow heart development in potatoes (4) as well as delayed maturity and shorter storage life in potatoes and onions. Of major concern to potato growers is the darkening of the processed product with high nitrogen that could make the crop unacceptable for processing. High nitrogen levels can cause off-flavors in canned carrots. Excessive nitrite accumulation in vegetables should also be of concern. Overuse of phosphorus fertilizer can result in deficiencies of zinc (6) as well as lower the specific gravity of potatoes. Although low levels of potassium are seldom encountered in Prairie soils, deficiency of this element can cause darkening of potatoes, loose heads in cabbage, short spindly carrot roots, and poor bulb formation in onions. While excessive levels of potassium can reduce the dry matter of potatoes, the sulfate form of potassium improves chip color and increases specific gravity of potatoes compared to muriate of potash (3).

Potatoes and vegetables generally require relatively high soil fertility in comparison to other crops. This is partly due to the amount of foliage produced by crops such as potatoes and cabbage. Table 2 shows that the amount of nitrogen removed from the field by the harvested portion of these crops is somewhat greater than a crop such as hard spring wheat. A comparison of fertilizer recommendations from each of the Prairie provinces showed in some cases, great differences in levels of fertility considered ideal for each of the crops. It is difficult to separate the influence that environment, soil type, and cultivar have on these recommendations. For rutabagas and carrots, similar soil nitrogen levels are suggested in all provinces those being 60 kg/ha and 70 - 100 kg/ha, respectively (Table 3). Manitoba recommends nitrogen levels substantially higher than the other two provinces for onions and cabbage with the most extreme case being for cabbage in which the rate suggested is 105 kg/ha higher than in Saskatchewan. Higher nitrogen rates for potatoes grown in Saskatchewan and Alberta may be due to the greater proportion of potatoes in these provinces going into the fresh market and therefore there is no concern about nitrogen's effect on processing color.

Phosphorus recommendations are somewhat more consistent across the three Prairie provinces than for nitrogen with an application rate of 100 - 130 kg/ha $P_{2.5}O_5$ recommended (Table 4). However, Alberta recommends extremely high rates for potatoes in comparison to Manitoba and Saskatchewan while recommending much lower rates of phosphorus in onions than do the other two provinces. Generally, addition of potassium is not required for any crop except perhaps in some lighter soils because of the high levels of potassium in most regions. A consensus seems to be that a minimum requirement of 450 kg/ha available potassium is sufficient for all crops. Although micronutrients have not been of much concern in the past, in some areas, particularly on lighter soils and in fields cropped frequently with potatoes or canola, sulfur deficiencies may be showing up. Some potato growers have also begun applying zinc.

In summary, the major concern with fertility recommendations for potatoes and vegetables grown in the Prairie region is that little effort has been spent on the Prairies in evaluating various fertilizer programs and their influence on fresh and processing quality and storage, life, and yield. Although some research is being done with potatoes, most recommendations for vegetables are based on data from other producing areas. The advantages of banding versus broadcast fertilizer applications are well known, yet many growers may still be using the less efficient broadcast method. The increasing use of fertigation is likely improving crop production but more studies on the optimal timing of fertilizer application are needed. Fertilizer effects on crop maturity as it affects date of harvesting and storage capabilities need to be further researched. The introduction of new cultivars requires updating of fertilizer recommendations to assure optimum yields and quality. The relationship of plant populations to fertility requirements needs attention particularly for the vegetable crops as almost no work has been done in this area. Although growers have recently been made aware of over-application of fertilizers, they must be informed of the consequences of excessive use of nitrogen and phosphorus.

REFERENCES

1. Alberta Horticultural Advisory Committee. Alberta Vegetable Production Guide 1985-86. Alberta Agriculture Agdex 250/13-1.
2. Anonymous 1985 Vegetable Crop Production Guide. Manitoba Agriculture.
3. Minotti, P.L. 1975. Plant Nutrition and Vegetable Crop Quality. In Proceedings of the symposium: Plant Nutrition and Horticultural Products Quality. Hort. Science. 10: 54-56.
4. Olday, F.C. 1979. Influence of Soil Fertility on Vegetable Quality. In Proceedings - 1979 Illinois Vegetable Growers Schools. University of Illinois at Urbana-Champaign, Agric. Exp. Stn.
5. Pritchard, M.K. 1983. Nutrients Removed by Vegetable Crops. Department of Plant Science, University of Manitoba.
6. Wittwer, S.H. 1969. Regulation of Phosphorus Nutrition of Horticultural Crops. In Proceedings of the symposium: The Role of Phosphorus in Plant Growth. Hort. Science 4: 320-322.

Table 1. Vegetable production on the Prairies, 1984.

	HECTARES	GROSS RETURN	
		PER HA	PER ACRE
Potatoes	25,500	\$ 2,275	\$ 920
Onions	360	6,950	2,800
Carrots	350	9,090	3,680
Cabbage	415	4,490	1,980
Rutabagas	105	6,817	2,760

Figure 1. Root systems of various crop plants.

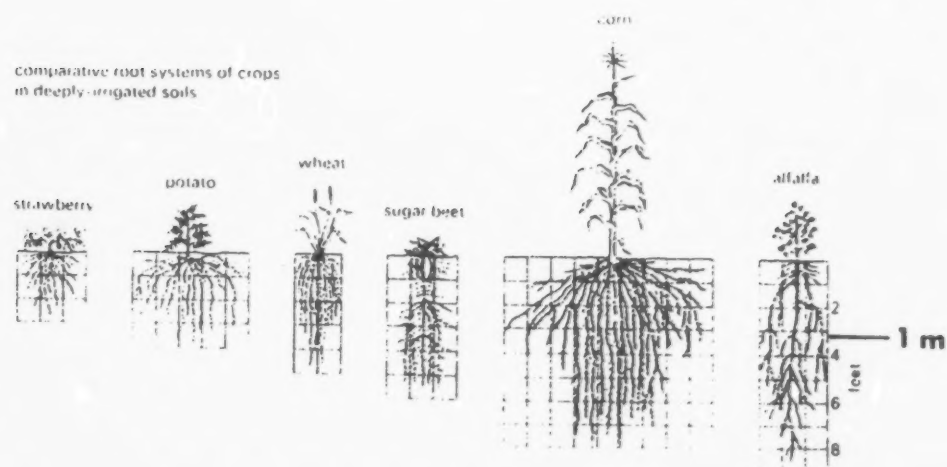


Table 2. Nutrient removal by vegetables* (5).

CROP	NITROGEN (kg/ha)	PHOSPHORUS (kg/ha as P_2O_5)
Potatoes	84	28
Onions	86	21
Carrots	65	35
Cabbage	57	21
Rutabagas	64	28
Wheat	53	-

* Based on an "average" yield of harvested product.

Table 3. Comparison of provincial fertility recommendations for vegetables - Nitrogen (1,2).

CROP	KG/HA (TOTAL - SOIL + ADDED)		
	MAN.	SASK.	ALTA.
Potatoes	100	165	150
Onions	130	70	40
Cabbage	190	85	95
Carrots	90	70	100
Rutabagas		60	

Table 4. Comparison of provincial fertility recommendations for vegetables - Phosphorus (1,2).

CROP	ADDED P_2O_5 (KG/HA)		
	MAN.	SASK.	ALTA.
Potatoes	50	80	165
Onions	130	100	50
Cabbage	160	100	100
Carrots	130	100	130
Rutabagas	130	100	124

FERTILITY MANAGEMENT TO OPTIMIZE CANOLA YIELDS

by J.T. Harapiak

Oilseed crops, particularly canola/rapeseed have been of considerable importance to western Canada's agricultural economy. Although average canola yields have been increasing more rapidly in the past decade than has been the case for cereal crops, average canola yields have generally been considered less than satisfactory and significantly below what could be achieved if current technology was being properly applied. Canola has demonstrated itself to be quite responsive to improved farm management practices. Top yields are consistently associated with farmers who modify and adapt existing crop management factors into an integrated canola production package that takes into consideration the unique requirements of this crop.

Although canola is extremely responsive to crop inputs such as fertilizer, there are many other management practices that can be modified to the benefit of canola yields without significantly increasing production costs. Many of the principles involved in producing top yielding canola crops have evolved from a survey of the production practices of above average canola producers that was conducted in central Alberta (Thomas, 1982). A properly established and managed canola stand is essential before consideration should be given to investing increasing amounts of dollars into expensive crop inputs such as fertilizer.

Effective Crop Establishment Key to Higher Yields

Although the best tillage and planting systems for canola will vary with soil types and may also vary somewhat from year-to-year depending on climatic conditions, there are nevertheless some important principles that have evolved with respect to establishing canola stands with a higher yield potential. In that respect, there are no field operations more closely associated with success or failure in canola production than is the preparation of a proper environment for rapid and uniform germination of the seed.

Canola seedlings develop slowly and are more vulnerable to weed competition and diseases at this stage than are cereal crops. It has been estimated that under dryland farming conditions, stand establishment problems can account for 65% of the yield difference between farmers achieving top canola yields and those only achieving average yields (Thomas, 1982). This same study indica-

-
1. Presented at "Irrigation on the Prairies", The Fourth Annual Western Provincial Conference on Rationalization of Water and Soil Research and Management. Saskatoon, Saskatchewan, November 25-27, 1985.
 2. Manager, Agronomy & Market Development, Western Co-operative Fertilizers Limited, P.O. Box 2500, Calgary, Alberta T2P 2N1.

ted that about 25% of the yield loss could be attributed to less effective weed and pest control, but only 10% due to reduced applications of fertilizer. The average difference between farmers achieving top yields and average yields amounted to 20 bushels/acre.

Seedbed Preparation and Seeding

For canola, the seedbed must be reasonably level, uniformly well packed, slightly lumpy on the surface, free from growth and moist to the surface to insure uniform and rapid growth.

Seedbed Firmness - A firm, well packed seedbed provides the type of excellent soil-seed contact that is required to insure rapid germination and the establishment of a vigorous stand with a higher yield potential. The results summarized in Figure 1 from the Alberta survey (Thomas 1982) graphically illustrate that loose seedbeds were associated with low yields while higher yields were associated with seedbeds that producers rated as being firmly packed. Excess tillage in the spring of the year is one of the major contributors to loose, dry seedbeds.

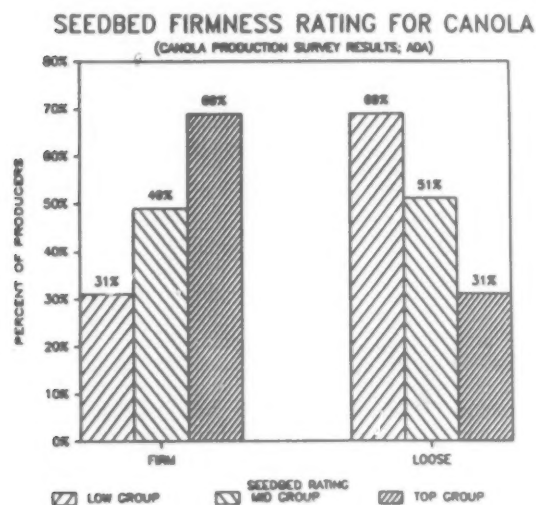


Figure 1. Relationship of canola seedbed firmness to yield category of farmers participating in the Alberta Canola Production Survey (Thomas, 1982).

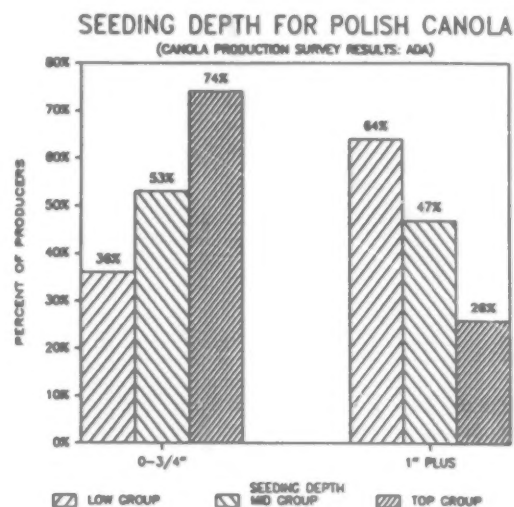


Figure 2. Relationship of canola (*Brassica campestris*) seeding depth to yield category of farmers participating in the Alberta Canola Production Survey (Thomas, 1982).

Seeding Depth - A properly prepared seedbed is essential to maintaining effective and uniform depth control during the seeding operation. Excessively pulverized or loose, cloddy seedbeds are therefore undesirable and tend to dry out rapidly. Canola seed sown to a depth of 1/2 to 1" into a firm, moist, warm seedbed germinates rapidly with a high percentage of emergence and survival. The data illustrated in Figure 2 graphically illustrates that based on a survey of the practises of above average Alberta canola producers (Thomas, 1982), top producers consistently seeded their

canola crop at a shallower depth. It should be kept in mind that because of the very shallow seeding required for achieving top yielding canola crop, seedrow applied phosphate is vulnerable to being stranded in a dry surface layer of soil if during the growing season the crop is subjected to a period of moisture stress.

Seeding Date - Selection of the proper seeding date involves a compromise between minimizing risk factors and maximizing yield potential. Early seeding dates are more important for achieving top yields with the "Argentine type" varieties (*Brassica napus*) which require a longer growing season to mature. The results of the Alberta survey of above average canola producers (see Figure 3) indicated that top yields were consistently associated with an earlier seeding date most usually in the first two weeks of May. It should, however, be noted with the lower yielding and earlier maturing "polish type" varieties (*Brassica campestris*), seeding too early tended to result in lower yields with top yields being associated with a mid-May or slightly later seeding date.

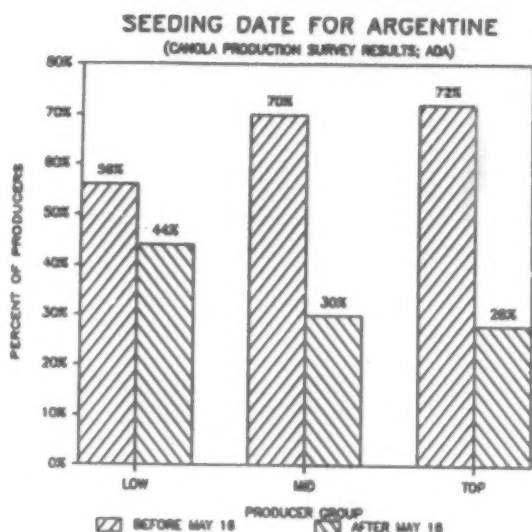


Figure 3. Relationship of canola (*Brassica napus*) seeding date to yield category of farmers participating in the Alberta Canola Production Survey (Thomas, 1982).

Other Management Factors Need to be Considered

There are, of course, many other management factors to consider in producing high yielding canola crops that are equally important to those mentioned above. These include the selection of proper varieties, rotations, use of good quality seed, the application of proper weed, pest and disease control techniques as well as the use of proper harvesting procedures. These other crop management factors will not be dealt with in this discussion. However, seedbed quality, seeding depth and seeding date have been included in this presentation because these management factors can potentially be strongly influenced by the approach that is selected for providing the required fertilizer. For a complete discussion of all aspects of producing canola, the reader is referred to the "Canola Growers Manual" (Thomas, 1984).

Increased Fall Work Contributes to Improved Seedbed Quality

Despite the fact that high fertility levels are extremely important to the production of high yielding canola crops, simply applying extra fertilizer does not guarantee higher yields. A completely integrated management approach is required that takes into consideration all aspects of canola production. In the case

of fertilizer application, care must be exercised to insure that in the process of attempting to accomplish effective and efficient use of the fertilizer inputs that seedbed quality and proper seeding date not be sacrificed to the detriment of crop yields.

The survey of the 300 above average Alberta canola producers (Thomas, 1982) provides an indication that the top canola producers were very cognizant of the contribution of seedbed firmness, seeding depth and seeding date to higher yields. They

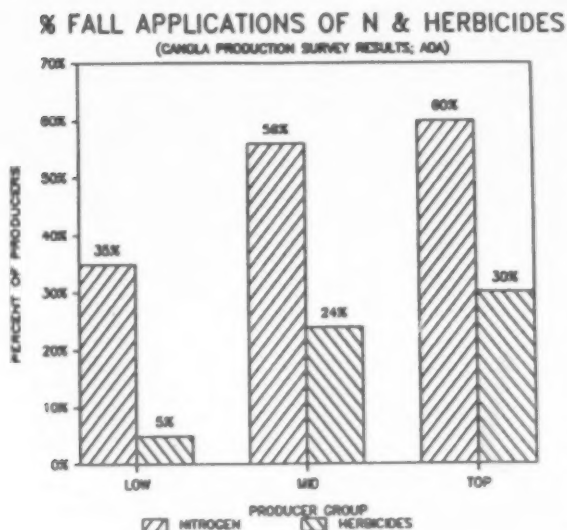


Figure 4. Frequency of fall fertilizer and herbicide application according to yield category of farmers participating in the Alberta Canola Production Survey (Thomas, 1982).

attempted to spread the workload by accomplishing more of the required preparation for producing a high yielding canola crop in the fall of the year (see Figure 4). This approach would obviously contribute to a better seedbed and more timely planting. The lower yielding group of farmers tended to conduct more tillage operations and more herbicide application in the spring of the year. A high percentage of the top yielders deep banded the bulk of their fertilizer requirements in the fall of the year, while the low yielding group tended to broadcast and incorporate their fertilizer requirements in the spring of the year. This fact could obviously result in a compromise in terms of the ideal seedbed and the ideal seeding date.

It is readily apparent that more emphasis needs to be placed on

fall banding of fertilizer and fall application of herbicides in order to minimize moisture robbing spring tillage operations. This fact will help conserve surface moisture that is essential to germinate canola seeded at a shallower depth. Reduced spring work will also result in firmer and more uniform seedbeds that will help contribute to more rapid and uniform early crop growth. The potential benefits of this approach to the production of higher yielding irrigated canola crops is confirmed in an Alberta Agriculture survey of the production practises of successful irrigation canola growers (ADA, 1980).

Differences in Canola Varietal Responses to Fertilizer

The slower maturing "Argentine type" (*Brassica napus*) varieties have approximately a 20% yield advantage over the "Polish type" (*Brassica campestris*) varieties. The data obtained in some trials conducted by Alberta Agriculture (Penney, 1985) indicated that the yield differences observed between Tobin (*B.campestris*) and Westar

(*B.napus*) would be somewhat dependent on the level of fertilizer nitrogen applied (Figure 5) since the response pattern to increasing rates of nitrogen seems to vary between these two canola varieties. In fact, the data suggests that the consequence of under-fertilizing the higher yielding Westar variety were more detrimental than in the case of the lower yielding Tobin variety. It also appeared that the response curve leveled at a lower rate of nitrogen for the Polish than for the Argentine type variety.

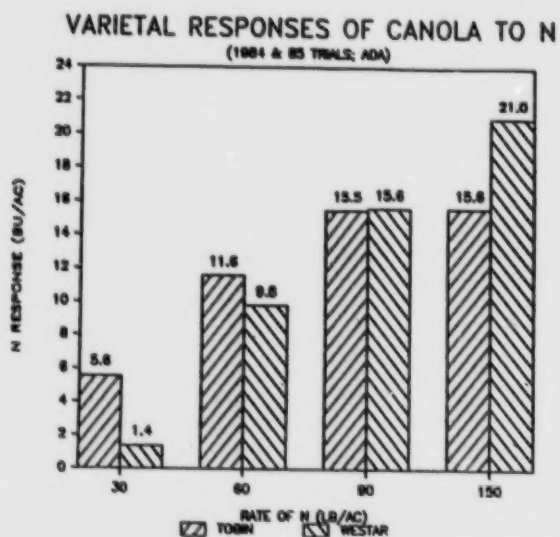


Figure 5. Variations in response to nitrogen between Argentine type (Westar) and Polish type (Tobin) canola (Penney, 1985).

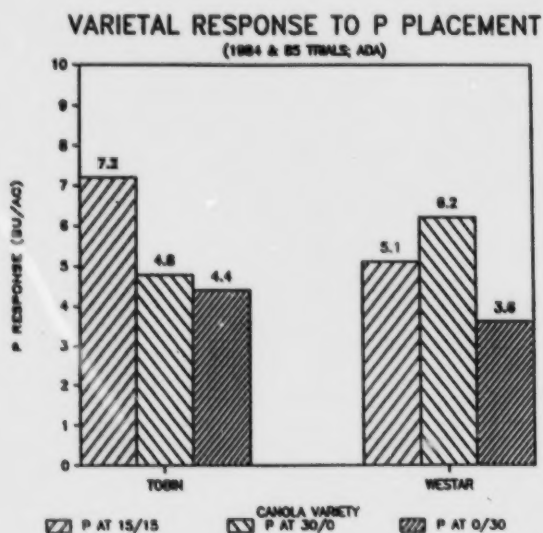


Figure 6. Variations in response to method of phosphate (P_2O_5) placement (Ratio of Seedrow/Deep Band) between Argentine type (Westar) and Polish type (Tobin) canola (Penney, 1985).

The data presented in Figure 6 suggests that there may also be important canola varietal differences in the response patterns to phosphate placement (Penney, 1985). A total of 30 lbs/acre of phosphate was applied in three different methods at several sites that were quite responsive to phosphate fertilizer. In the case of the smaller seeded Polish type canola (ie. Tobin), the largest phosphate response was obtained when the phosphate was equally split between the seedrow application and deep banded with the nitrogen. In the case of the larger seeded Argentine type (ie. Westar), the largest response to phosphate was obtained when all of the phosphate was placed directly in the seedrow. The smallest response to phosphate for both canola varieties was obtained when all of the phosphate was deep banded with the nitrogen which was applied as urea at the rate of 90 lbs N/acre. It would appear that the smaller seeded Tobin may have been less tolerant of phosphate applied directly in the seedrow than was the larger seeded Westar. It should be kept in mind that the source of phosphate

was mono-calcium phosphate (ie. 0-45-0) which is considered to be less detrimental applied in the seedrow than is mono-ammonium phosphate (ie. 11-51-0) which is the usual commercially available source of phosphate in western Canada.

In these trials the average response to 15 lbs of P_2O_5 applied in the seedrow amounted to 2.6 bushels/acre compared to 6.1 bushels/acre to 30 lbs of P_2O_5 applied in a split application. The top average response (ie. 6.8 bushels/acre) occurred when 45 lbs/acre of P_2O_5 was deep banded together with the nitrogen.

Response of Canola To Phosphate Placement

Because canola is relatively small seeded, it is recommended that less fertilizer be placed directly in the seedrow than in the case of cereal crops. Despite the fact that canola has a higher requirement for phosphate than cereal crops, less phosphate is frequently recommended for canola due to the more severe restrictions for seedrow application with this crop. Generally, not more than 20 lbs/acre of P_2O_5 should be applied in the seedrow for canola when using the usual commercially available mono-ammonium type of phosphate fertilizers.

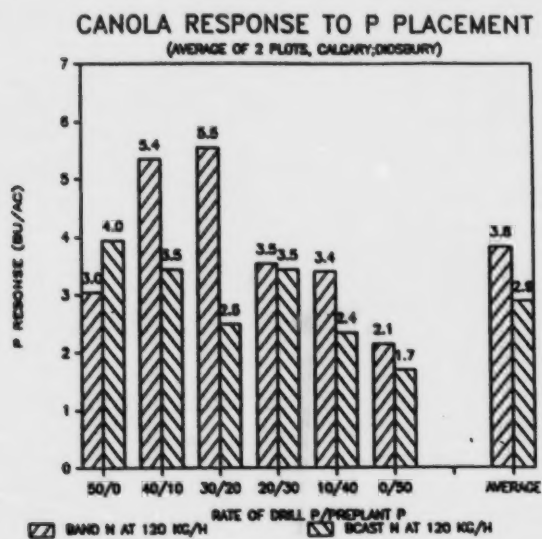


Figure 7. Response of canola to variations in ratio of pre-plant (deep band or broadcast and incorporated) to drill-in (starter) phosphate (WCFL).

The development of the "deep banding" concept of fertilizer applications has provided farmers with the technology to effectively apply the additional phosphate required on very P deficient soils for production of higher yielding canola crops. Some recent research conducted by WCFL agronomists (see Figure 7) has provided guidelines as to the proportion of the phosphate that should be applied in the seedrow or applied in the pre-plant application with the nitrogen (either deep banded or broadcast). In these trials, the variety of canola was Tobin. One of the trials was irrigated while the other was dryland. The rate of phosphate application was 50 kg P_2O_5 /ha applied as mono calcium phosphate.

In the cases where the pre-plant application was deep banded, top yields were achieved when the phosphate was split between the seedrow and the deep band. The highest response to phosphate was achieved when 60% of the phosphate was placed in the seedrow and

the rest was deep banded with the nitrogen. If the commercially available nitrogen containing form of phosphate had been applied (eg. 11-51-0), it would normally be suspected that yields would have peaked at a lower proportion of the phosphate in the seedrow due to the potentially adverse effects of the phosphate fertilizer on seedling emergence. However, more recent research with mono-ammonium phosphate (ie. 11-51-0) also suggests that at least 50% of the phosphate should be placed directly in the seedrow as a "starter" to achieve maximum yields.

The total response to the phosphate was generally lower when it was broadcast applied with the nitrogen. The exception to this trend was in the case where 100% of the phosphate was drill-in applied. This could possibly be attributed to the fact that the drill-in phosphate was in closer proximity to the broadcast applied nitrogen than to the deep banded nitrogen thereby aiding in phosphate uptake. Results from similiar irrigated trials are summarized in Table 1.

Table 1: Response of Irrigated Canola To Variations in Proportion of Drill-in and Pre-Plant Applied Phosphate (WCFL, 1983)

Pre-Plant & Drill-in Treatments (kg/ha)	Yield (Bushels/Acre)	
	Band	Broadcast
1) 0-0-0	20.3	
2) 120-0-0	37.8	32.5
3) 120-0-0 + 50	41.4	35.7
4) 120-10-0 + 40	42.8	34.4
5) 120-20-0 + 30	43.7	33.4
6) 120-30-0 + 20	42.4	35.3
7) 120-40-0 + 10	42.3	34.8
8) 120-50-0 + 0	40.5	33.4
Average	41.6	34.2

+ Indicates rate of drill-in P_2O_5 (kg/ha)

Note: Pre-plant treatments were fall applied.

Under conditions of early season moisture stress where the soil surface is subject to being dried out, it has been observed that the response to phosphate deep banded together with nitrogen prior to seeding can be significantly larger than the response to phosphate applied directly in the seedrow. Under these conditions, it is assumed that uptake of drill-in phosphate is hindered by the fact that it is "stranded" in the dry surface soil from which crop uptake is not possible until the soil surface is remoistened. This problem can be aggravated by the very shallow seeding depth that is recommended for achieving top yielding canola crops.

Interference with P Uptake from Dual Bands

Research conducted with barley and soft spring wheat (Harapiak & Flore 1985, Harapiak and Penney 1984) has demonstrated that higher rates of nitrogen in freshly applied dual N-P bands can interfere with P-uptake from these bands. Recent research by WCFL agrono-

mists has confirmed that a limited canola response to deep banded phosphate can also occur from freshly applied dual N-P bands at higher rates of N application. At a band spacing of 12", interference with P-uptake from the dual bands appears to occur as rates of nitrogen (applied as urea) approach 90-100 lbs N/acre. This interference appears to be minimized if the bands are allowed to incubate for a period of 3 weeks. No such problem has occurred when the N-P bands are applied in the fall of the year.

Variations in Crop Type Responses to Phosphate Placement

It could be predicted that based on the variation of rooting habits that are evident between various crops, that the response to phosphate applied in different manners would vary between crops such as barley and canola. Recent research at the Agriculture Canada Research Station at Brandon has confirmed that this is indeed true (Bailey, 1985). Four methods of phosphate placement were tested (ie. BC - broadcast and incorporated; PWS - placed with the seed; PSS - placed 1" to the side and 1" below the seedrow; PBS - placed 1" below the seedrow) for four types of crops. The data summarized in Figure 8 represents the maximum response achieved to phosphate over a wide range of application rates.

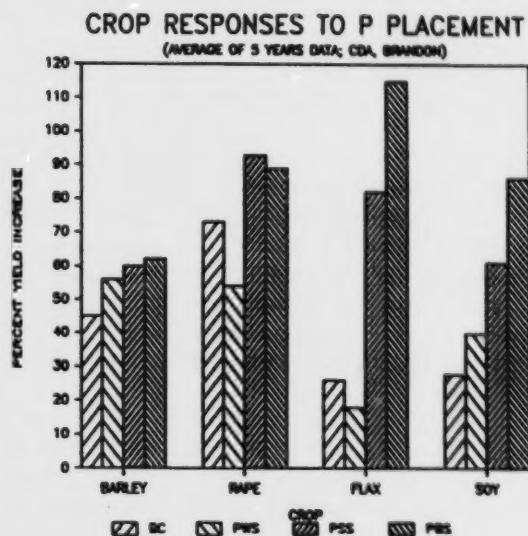


Figure 8. Comparisons of maximum response by four crops to a range of phosphate rates applied by four different placement methods (Bailey, 1985).

It is obvious that barley was the least affected by method of P placement. For canola, a higher rate of broadcast applied phosphate was more effective, but not necessarily more economical than the most effective rate of drill-in applied phosphate. The most interesting feature of this data is the striking benefit of side-band or below the seedrow placement of phosphate for flax. Similar but less striking trends were evident for soybeans.

These results confirm that maximum canola yields cannot be achieved by simply applying the maximum amount of phosphate that can be safely tolerated directly in contact with the seedrow. Based on previously presented data, it is obvious that some form of split phosphate application is required to achieve top canola yields.

Supplying Sulphur for Canola

Canola has a high sulphur requirement and reports of sulphur responses by this crop have become much more frequent during the past decade. As illustrated in Table 2, the consequences of a severe sulphur deficiency can be very serious for canola if the fertilizer program does not include sulphur (Thomas, 1984).

Table 2: Prairie Wide Response Pattern of Canola to NPKS Treatments on Very Sulphur Deficient Sites

<u>Treatment</u>	<u>Canola Yield (Bushels/Acre)</u>
Check	12.7
NPK	6.3
PKS	14.3
NPKS	34.3

Soil testing has confirmed that the sulphur status within a given field can range from excessive to deficient. Collecting one composite soil sample can therefore mask a serious sulphur deficiency in parts of a field. Sulphur is usually least abundant in the better drained or upland portions of a field. If a sulphur deficiency is suspected, site specific soil sampling should be used in an attempt to isolate and identify areas where a deficiency of sulphur may be reducing canola yields. A sulphur deficiency can also be identified by collecting tissue samples from various parts of the field.

Canola has demonstrated an ability to recover quite well from a severe initial sulphur deficiency, providing the tap root comes in contact with a sub-soil reserve of available sulphur after the crop has become established (Bole and Pittman, 1984). Similarly, in an emergency situation, top-dressing of a readily available sulphur source can sometimes help salvage a seriously sulphur deficient crop. It should be noted that irrigation waters in western Canada can contain quite high levels of available sulphur (Bole, 1982).

There are many forms of sulphur available in western Canada. In situations of a serious sulphur deficiency, it is strongly recommended that sulphur in the oxidized form be applied. Elemental sulphur products can be used on marginally sulphur deficient soils if they are applied in the previous fall to allow a longer period for the granules to be at least partially oxidized. Elemental forms of sulphur can also be useful for long-term building of soil sulphur levels.

Research conducted in Alberta (Nyborg, 1985) indicates that the degree of sulphur oxidation in some of the typical sulphur-bentonite products (ie. typically contain 90% S) was minimal over an evaluation period of 3-12 weeks (see Figure 9). The rate of

oxidation was markedly improved when the sulphur was supplied in a very finely divided form (ie. suspension sulphur). Rates of oxidation were higher when the product was mixed into the soil rather than applied in a band.

The data presented in Figure 10 illustrates that cultivation following application of finely divided suspension sulphur helped speed the oxidation, particularly in the case where the sulphur was band applied. It would appear that cultivation results in more intimate and increased contact between the soil and the sulphur particles thereby speeding the oxidation process.

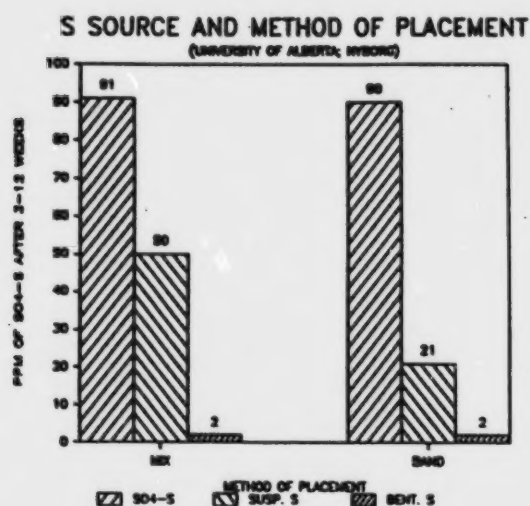


Figure 9. Influence of sulphur source on method of placement on availability of sulphate-sulphur after an incubation period of 3-12 weeks (Hyborg, 1985).

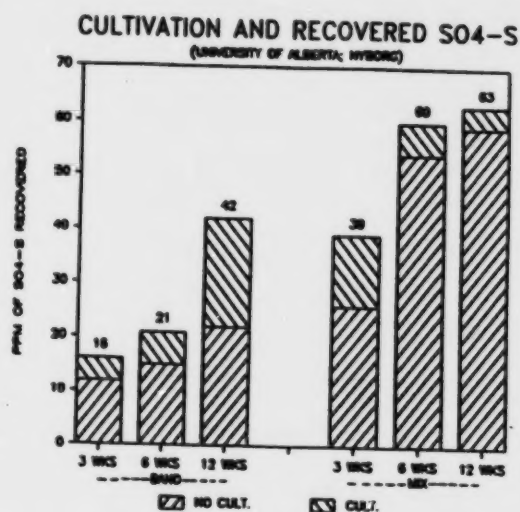


Figure 10. Influence of time, method of placement and cultivation on availability of sulphate sulphur from elemental sulphur applied as a finely divided suspension (Hyborg, 1985).

Canola Yield Potential - Dryland vs Irrigated

Canola is not known for its drought hardiness, therefore it could be expected that it would respond favourably to irrigation. The data summarized in Figure 11 indicates that in a Saskatchewan study (Henry and MacDonald, 1978), yields of irrigated rapeseed were more than double those obtained under dryland conditions. However, these yields are low given current standards. Under dryland conditions, given favourable climatic conditions, we now have the technology to produce 35 bushels/acre (2000 kilograms per hectare). Under irrigated conditions, experienced canola growers have clearly demonstrated that it should be possible to produce canola yields in the range of 50-60 bushels/acre.

The fact that canola is very responsive to irrigation is taken into consideration (Lavery, 1985) in the yield response predictive data that form the basis of soil nitrogen test recommendations (see Figure 12) used in Alberta and other provinces as well.

DRYLAND VS IRRIGATED CANOLA YIELDS (HENRY AND MACDONALD: U OF S)

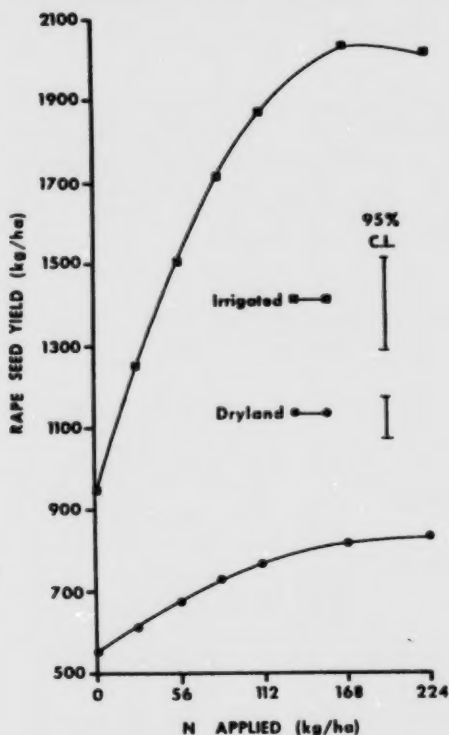


Figure 11. Relative response of irrigated and dryland canola to increasing rates of nitrogen (Henry and MacDonald, 1978).

CANOLA RESPONSE CURVES (ASFTL) (DRYLAND vs IRRIGATED CANOLA)

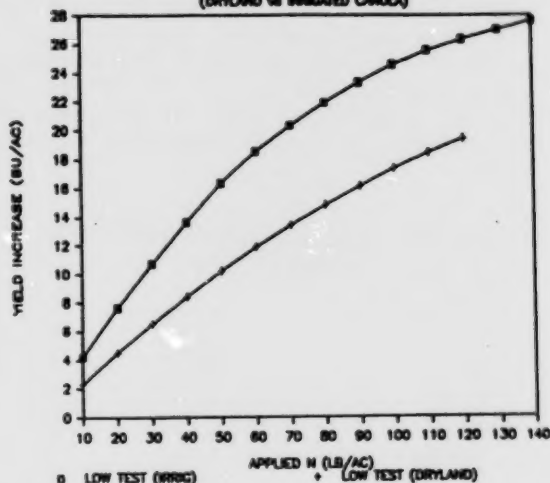


Figure 12. Predictive yield response curves survey used by the Alberta Soil and Feed Testing Laboratory for dryland and irrigated canola grown on fields testing low in soil available nitrate-nitrogen (Laverty, 1985).

Yield Goals For Irrigated Canola

Given favourable moisture conditions, a dryland yield goal of 35 bushels per acre is quite realistic. Research plot yields approaching 45-50 bushels/acre are not unusual. Some farmers have reported yields in the 60 bushel range given ideal growing conditions. Many irrigation farmers routinely produce canola yields in the range of 50-60 bushels/acre. Farmers practising superior crop management have demonstrated that irrigated yields approaching 70 bushels/acre can currently be achieved. As we develop better production packages for canola, it is likely that irrigated yield goals of 75 bushels/acre will be realistic. If the introduction of canola hybrids is successful, irrigated yield goals for the top growers of 85 to 90 bushels of canola may be within the realm of possibility within the next decade. If a hardy winter rape variety could be developed for the Canadian prairies, irrigated yields exceeding 120 bushels per acre could become a reality.

Fertility Requirements For High Yielding Irrigated Canola

One of the very serious shortcomings of making fertilizer recommendations for achieving high yields of irrigated canola is that very few fertility trials have been conducted in which high yields have been achieved. Since yield response curves are developed on the existing data pool of research plot yields that would be considered less than satisfactory by today's top growers of irrigated canola, it is possible that current recommendations based on soil testing are underestimating the fertilizer requirements to produce very high yielding irrigated canola crops.

The following is a program used by southern Alberta irrigation farmers who have produced yields of canola approaching 70 bushels/acre (Thacker, 1985):

- | | |
|-----------|---|
| NITROGEN | - 145 lbs of N deep banded, preferably in fall.
5 lbs of N applied as a seedrow starter.
30 lbs of N top dressed in the irrigation
water during the month of June. |
| PHOSPHATE | - 45 lbs of P_2O_5 deep banded with nitrogen.
25 lbs of P_2O_5 applied as a seedrow starter. |
| POTASH | - 33 lbs of K_2O deep banded with N & P_2O_5 .
17 lbs of K_2O applied as a seedrow starter. |
| SULPHUR | - 7 lbs of S deep banded with N, P_2O_5 & K_2O .
3 lbs of S applied as a seedrow starter. |

At the present time, there is very little data on which to predict potential micro-nutrient requirements for producing canola. The most likely micro-nutrient deficiencies that could develop in the future would include boron, copper and zinc.

Other Factors to Consider in Producing High Yields

As previously indicated, fertilizer is a key component in the formula for producing high yielding irrigated canola crops. However, simply applying more fertilizer is not a substitute for a well planned, technologically sound, integrated canola crop production package (Thacker, 1985). The following is a brief list of additional canola production factors that successful irrigated canola growers need to consider:

Seedbed Preparation - Conduct as much field work in the fall of the year as possible including the application of fertilizer and herbicide if necessary. Extra spring tillage can cause the seedbed to loosen and dry out. Extra spring operations can also result in yield robbing seeding delays.

Seed Selection - Use good quality seed of the Argentine varieties which have a 20% yield advantage over the Polish varieties of Canola. The longer growing period required to mature these higher yielding varieties should not usually present a problem in most irrigation areas. Consider selecting a newer variety such as Pivot that has a stronger stem and was specifically developed for irrigated conditions. Use dual purpose seed treatment.

Seeding - Consider the use of an end wheel press drill to avoid over-packing directly over the seedrow. A narrower row spacing is preferable (ie. 5-6") to obtain better seed distribution. Cross-seeding using 1/2 of the recommended seeding rate in each direction can help improve plant distribution and increase yields. Excessive seeding rates contribute to weak stemmed plants that are more prone to lodging. In some cases, cross-seeding has improved germination to the extent that it has made the crop more prone to lodging.

Seeding Date - It is important to seed as early as practical. Highest yields of Argentine type canola are associated with seeding in early May. Some southern Alberta farmers are prepared to accept the risks associated with seeding their canola in the latter part of the month of April.

Irrigation - A total of 15-18" of irrigation water is normally applied to canola. Canola requires irrigation late into the growing season. Irrigation should normally be continued until 1 week prior to swathing to achieve top yields (Krogman and Hobbs, 1975).

Swathing - Use a narrow (18 ft.) header. Consider expanding the swath opening from 4 ft. to 5 1/2 ft. for the purpose of producing wide, smooth swaths. Minimize bunching of the swath to reduce harvest losses due to uneven feeding of the swath into the combine.

Combining - Attempt to utilize full width of combine to reduce harvest losses. Larger combines (ie. 66" cylinder width) are desirable for harvesting high yielding canola crops.

REFERENCES

- Alberta Agriculture 1980. Irrigated Canola Production. Field Crops Branch. Agdex No. 149/156-1.
- Bailey, L. 1985. Personal Communication. Agriculture Canada Research Station, Brandon, Manitoba.
- Bole, J.B. 1982. Sulphur Fertilizers Not Required In Alberta. Agriculture Canada Newsletter, Lethbridge Research Station, Oct. 13, 1982.

- Bole, J.B. and U.J. Pittman 1984. Availability of Subsoil Sulphates to Barley and Rapeseed. Can. J. Soil Sc. 64: 301-312.
- Harapiak, J.T. and D.C. Penney 1984. Efficient Use of Nitrogen - The N & P Interaction. Alberta Soil Science Workshop, February 21-22, 1984.
- Harapiak, J.T. and N.A. Flore 1985. Effective Placement for Canola. Saskatchewan Soils and Crops Workshop, February 18-19, 1985.
- Henry, J.L. and B.K. MacDonald 1978. The Effects of Soil and Fertilizer Nitrogen and Moisture Stress on Yield, Oil and Protein Content of Rape. Can. J. Soil Sc. 58: 303-310.
- Krogman, K.K. and F.H. Hobbs 1975. Yield and Morphological Response of Rape to Irrigation and Fertilizer Treatments. Can. J. Plant Sc. 55: 903-909.
- Laverty, D.H. 1985. Personal Communication. Alberta Soil and Feed Testing Laboratory, Alberta Agriculture, Edmonton.
- Nyborg, M. 1985. Personal Communication, Department of Soil Science, University of Alberta, Edmonton.
- Penney, D.C. 1985. Personal Communication. Soils Branch, Alberta Agriculture, Edmonton.
- Thacker, L. 1985. Personnel Communication. Irrigated Canola Grower, Bow Island, Alberta.
- Thomas, P. 1982. Canola Production Survey Results. Alberta Agriculture, Field Crops Branch, Lacombe.
- Thomas, P. 1984. Canola Growers Manual. Published by the Canola Council of Canada.

Optimizing Alfalfa (*Medicago* spp.) Production

L.D. Bailey

Agriculture Canada, Research Station, Brandon, Manitoba

A paper presented by invitation at the 4th Western Provincial Conference,
Rationalization of Water and Soil Research and Management

Saskatoon, Saskatchewan

November 25-27, 1985

Alfalfa, the "Queen of the Forages", is a mainstay of today's agriculture. It comes close to the ideal cultivated crop in not only maintaining but improving the quality and productivity of soils on which it is grown, and in providing abundant nutritious sustenance as animal and human food. Alfalfa is the most popular forage legume grown worldwide and in Canada. From its origin in Iran, the crop spread, and was cultivated before the era of recorded history throughout Europe and Asia. It was introduced to N. America by Spanish and Portuguese colonists in the 16th century. However, it was not until sometime in the 1850's when Wedelin Grimm developed and released his winter-hardy "Grimm strains" of alfalfa that the crop began to spread throughout the N. American continent.

Alfalfa was first introduced into Canada in 1871 in Ontario. About 1908, successful alfalfa production began in Western Canada with the introduction of the winter-hardy Grimm cultivars. Concomittent with on farm production was research in breeding and production management. Today, after only approximately 100 years,

Canada grows 4-5 million hectares of alfalfa in pure and mixed stands (grass-alfalfa). The crop is the standard of excellence against which all other forage crops are measured. But, like reigning monarchs, alfalfa does have problems that prevents it from reaching its full potential. Probable the main flaw is that it may cause bloat in ruminants when used as a pasture legume. In reviewing the literature and discussing the topic with colleagues, for the preparation of this paper, it became apparent that there are a hosts of other problems associated with alfalfa production that are not addressed or only receive minimal research effort. All of these problems affect alfalfa production and may have significant effect on optimizing alfalfa forage yield and quality.

Pre-planting Planning

At least 1 year prior to seeding the crop it is necessary to identify the field on which it is to be sown, determine the weed problem and begin weed control and eradication measures, analyze the soil for nutrient composition, and begin a consultative process with experts on alfalfa production.

Cultivar and Seed Selection

Select and use only the cultivars recommended for your area that has the advantage of higher yield, better disease resistance, and improved agronomic characteristics. In this respect Goplen (personal correspondence, 1985) states - "Breeding objectives for alfalfa vary according to the region where it is grown. For example, the occurrence and prevalence of diseases and insects vary across N. America. In regions where temperatures are moderate and moisture more plentiful, there are more problems with insects and diseases. Thus plant breeders must breed

alfalfa for multiple pest resistance, because of races within diseases and insect pests, these breeding objectives are quite complex". Winter temperatures and winter conditions pose a major limiting factor to alfalfa production. In areas where winters are mild, non-dormant alfalfas are grown and production occurs over a long growing season, several cuts are taken annually. However, as winter conditions become progressively colder, one must breed semi-dormant to highly dormant varieties. The latter is the case for Western Canada. Goplen (personal correspondence, 1985) suggests that there is a negative correlation between winter-hardiness and crop recovery after cutting, thus one must sacrifice yield for winter-hardiness. Therefore, for Western Canada, to optimize yield, one must use cultivars with minimum winter-hardiness required for the plant to survival. Hanna (personal correspondence, 1985) states that - "the progress that plant breeders have made over the years has been rather slow. The principal way in which we have contributed to maximization of yield has probably been just to hold the line against disease and insect problems." He suggests that because of development of varieties with resistance to bacterial wilt, phytophthora root rot, stem nematode, verticillium wilt, etc. we are able to maintain current yield levels. He also indicated that the introduction of flemish alfalfas has increased forage yields in the dryer regions of Western Canada, particularly the irrigated area of Southern Alberta. However, he cautions that these high yielding cultivars should not be "pushed" beyond their capabilities. They are less winter-hardy and persistent than our standard varieties and have limited usefulness outside British Columbia, Southern Alberta and Southern Ontario. They often perform well for the first two years or so, but then their lack of winter-hardiness results in lost of stand and yield. For example, at Swift Current, Saskatchewan, under irrigation they out-

yielded Beaver by approximately 10% during the first two years of production, there after yield decline below that of Beaver and their usefulness was lost.

Seed Inoculation

Inoculate seeds with recommended inoculants immediately prior to seeding. Alfalfa is a legume crop and thus will co-exist with Rhizobium bacteria in a symbiotic relationship. The bacteria infects the root hairs of the plant and form nodules. These nodules are enlarged plant cells filled with bacteria. In the nodules the bacteria, using energy (carbohydrates) from the plant, convert atmospheric nitrogen into nitrogen forms that the plant can use. The process is called symbiotic nitrogen fixation. The Legume-Rhizobium bacteria relationship is very specific. Thus Rhizobium meliloti the bacteria that would infect and fix nitrogen in association with alfalfa and sweet clover will not effectively infect and fix nitrogen with other legumes. Under ideal conditions an established stand of alfalfa will be provided with all of its nitrogen through symbiotic nitrogen fixation. The alfalfa roots should be checked periodically for the presence of nodules. Large nodules that are bright pink when cut open are a good indication that nitrogen fixation is occurring.

Seeding Management

Place seeds in a shallow well-prepared, moist and weed-free seedbed. The small seed of alfalfa need special care to establish a good stand. The seeds should be placed no more than 20 mm deep in a firm seedbed that is free from weeds and has moisture near the surface. This is essential since the seedlings are poor competitors with weeds and deep placement of seeds results in poor emergence. Row

spacing vary with moisture availability. In moister regions rows of 15 to 20 cm are used while in the dryer areas row width ranges from 30 to 60 cm.

Alfafla should be seeded alone. One or two cuts of alfalfa can be obtained in the seeding year when it is sown alone in all but the dry areas of Western Canada. Waddington and Bittman (1983, 1984) reported that alfalfa seeded without a companion crop produced more dry matter in the seeding year, the effect carried over into the first harvest year. From their studies it would appear that annual cereals are better companion crops than rapeseed.

Where soils are susceptible to erosion a companion crop may be beneficial in minimizing soil erosion in the establishment year. When a companion crop is used it should be seeded first and at about one-half the normal recommended seeding rate. The alfalfa is seeded at the suggested depth at right angle to the companion crop. Companion crops compete with the alfalfa for nutrient and moisture, thus the vigor and growth of the alfalfa is reduced and harvesting of the alfalfa in the establishment year may not be possible. Seed alfalfa in early spring. Seeding alfalfa in August gives less than a 50% chance of successful stand establishment. Similarly, "dormant-seeding" in mid- to late October, when temperatures are sufficiently low to prevent germination, resulted in less than satisfactory stand development. The best emergence and stand development were from May seedings.

Fertilizer Management

Use soil and plant analysis to determine the nutritional status of the crop and added fertilizers to correct any identified deficiency. A number of factors must be taken into account when determining the nutritional requirement of

alfalfa. The crop commence to grow early in the spring and grows throughout the summer into the late fall. Thus an understanding of climatic as well as edaphic factors must be considered when recommending fertilization of alfalfa swards.

Soil Type: Alfalfa can be grown on all soils except those that are poorly drained or too coarse textured to retain moisture. Bailey (1980) reported that coarse textured soils associated with high water table can be as productive as fine textured soils if fertility and moisture conditions are adequate. Alfalfa tolerates moderate salinity and can be established on soils with a conductivity of 4 dS m⁻¹. An established stand, however, will tolerate salt levels of 8 dS m⁻¹ if its nutritional needs are met. Because soil acidity interferes with nitrogen fixation by Rhizobium bacteria it is very difficult to establish alfalfa on highly acidic soils. Consequently, soils with a pH of 6.5 or lower should be limed to a pH of 7.0. Most prairie soils have a pH of 7.0 or higher and are suitable for alfalfa production.

Yield potential: Bailey (1983) reported that three annual harvests of alfalfa can be taken without any adverse effects on stand density and longevity, provided that the crop is supplied with an adequate supply of nutrients. In regions where moisture is generally very low, a two harvest system may be desirable. Similar, under irrigation, with adequate fertility four or more harvests may be possible. In the three harvests system, Bailey (1983) obtained yields in excess of ten tons per hectare of forage with protein content in excess of 18%. He also reported that for optimum yield and protein, harvesting should occur at 'full bud' and not later than the 5% bloom stage of growth (Fig. 1). Delaying harvest beyond this time will result in minimum increase in forage yield but a significant reduction in protein. Between the 2nd and 3rd harvest, Bailey (1980) recommends that there

should be at least a six week period of growth so that the crop could prepare for over-wintering by accumulating and storing carbohydrates in its roots. The 3rd harvest then, on the prairies, should be taken in October after the first killing frost.

Nutrient removal: Harvesting alfalfa forage results in a continuous depletion of mineral nutrients from the soil. Table 1 shows that under a three cut management system, a high yielding crop of alfalfa uses a tremendous amount of the four major plant nutrients. In comparison a 2690 kg/ha crop of wheat used approximately 1/4 as much nitrogen, 1/2 as much phosphorus and sulphur and 1/6 as much potassium as a 12 t/ha crop of alfalfa. This large removal of nutrients by alfalfa makes it essential to annually monitor the soil fertility and forage nutrient composition by soil and plant analysis.

Response to fertilizer: Alfalfa is very responsive to applications of fertilizer. Bailey (1982) reported forage yield increases of 39, 27, and 38% for the 1st, 2nd and 3rd cuts respectively, on clay loam soils and on sandy loam soils the increases were 300% for the 1st and 2nd cuts, without fertilizer there were no 3rd cut (Table 1). The protein content increased on the clay loam soils by 25 to 38% and by greater than 120% on the sandy loam soils with the addition of fertilizer.

Even though research has shown that alfalfa responds to good fertilizer management, the percentage of alfalfa crops which receive fertilizer on the Canadian prairies is very small, about 15 to 25% of the total alfalfa cropped area.

Fertilizing at establishment: Because it has a small seed, alfalfa needs a readily available supply of phosphorus and other plant nutrients right after emergence. It is generally accepted that by the time a young plant has attained about

25% of its total dry weight, it may have already accumulated as much as 75% of its total phosphorus. High rates of fertilizer placed with the seed will however, damage the seedlings. Thus when potassium and sulphur are recommended, they should be broadcast and worked into the soil or drilled prior to seeding to a depth of 7.5 to 10 cm. The best response to phosphorus fertilizer as measured by phosphorus utilization and seeding vigor is obtained when the phosphorus is placed 2.5 cm directly below the seed. Good response is also obtained when the phosphorus is placed 2.5 cm below and 2.5 cm to the side of the seed. Placing the phosphorus greater than 2.5 cm to the side of the seed, or broadcasting and incorporating it into the soil, reduces its effectiveness to the new seedling. If machinery for specific placement of phosphorus fertilizer is not available, the fertilizer may be broadcast and incorporated 7.5 to 10 cm into the soil.

Fertilizing established stands: Increased use of fertilizer, use of improved varieties, herbicides, insecticides, improved management and, in some areas irrigation have resulted in increased yield of alfalfa forage. This increased production of high quality forage has resulted in increased removal of mineral nutrients from the soil. In reviewing the literature on the nutrition and fertilization of alfalfa it was observed that most experiments on alfalfa fertilization were conducted at yield levels that are low by present-day standards. These results, are of questionable value and possibly misleading when making fertilizer recommendations for present-day alfalfa producers.

Nitrogen: Nitrogen is required by the crop for protein synthesis. Properly inoculated alfalfa will fix large quantities of atmospheric nitrogen. Bailey (1980) suggests that when conditions are adequate for optimum nitrogen fixation, the crop needs no additional fertilizer nitrogen. However, low rates of nitrogen

applied at the time of seeding will hasten and improve establishment and increase yield in the establishment year. Other researchers, however, have noted that nitrogen has a depressive effect on stand establishment. Response to nitrogen on established stands have been reported under dryland and irrigated conditions, which probably indicates relatively low efficiency of nitrogen fixation. On acid soils, where nodulation and nitrogen fixation may be poor alfalfa responds well to nitrogen application. The nitrogen content of high yielding, high protein alfalfa forage harvested at the full bud to 5% bloom stage is generally in excess of 3%. Therefore, because of this tremendous quantity of nitrogen removed from the soil by a high yielding, high protein crop of alfalfa, application of large rates of nitrogen, intended to meet the complete requirement of the crop may not be economical.

Phosphorus: The element plays a key role in many life processes. Much of the phosphorus is converted into organic form on entering the plant roots or in shoot meristematic tissues. These compounds are the energy compounds of the living cell. They provide energy to activate processes such as photosynthesis, carbohydrate and protein synthesis, transfer of heridity, and fat metabolism etc.

The majority of prairie soils are deficient in plant available phosphorus. A summary of soil test reports from Prairie laboratories for the period 1974 to 1980, show that 75% of the soils tested were in the very low to medium catagory for available soil phosphorus. Determining the phosphate requirement of alfalfa is a complex task due to the complexity of soil and environmental factors governing the availability of soil phosphorus to plants, the low recovery of phosphorus from fertilizer (35% to approximately 50%), and the low concentration of phosphorus in the forage (0.2% to 0.4%). This low concentration of phosphorus is

indicative of the relatively small amount of phosphorus removed from the soil by a crop of alfalfa forage. Thus it is generally interpreted that alfalfa does not require and will not respond to phosphorus fertilizers. Table 2, however, show that alfalfa will respond to applications of phosphate fertilizer at rates in excess of 60 kg P_2O_5 ha⁻¹. In these studies both yield and protein content were increased significantly. From studies conducted in Manitoba, Bailey (1980) reported that fall broadcast application of phosphorus fertilizer on established stands of alfalfa was an economical and effective management tool.

Potassium: It is generally believed that the majority of prairie soils contain sufficient plant available potassium for alfalfa production. However, recent studies have shown that initial exchangeable potassium level of a soil may not be an adequate criterion for determining the availability of soil potassium to alfalfa (Bailey, 1983). The author suggested that an assessment of the Potential Potassium Supplying Power (PKSP) of a soil may be a more useful tool. He found that soils with low PKSP and low exchangeable potassium required an annual application of 200 kg ha⁻¹ to produce maximum yield (Table 3). But there was also a significant response to potassium application on soils that tested in the medium and high ranges of exchangeable potassium. At maximum yield, taken at full bud, concentration of potassium in the forage was in excess of 2.0% and represented a large removal of soil and fertilizer potassium.

Potassium not only affects the yield of alfalfa forage but, the quality and also the general physiology and metabolic activities of the plant. Essentially, the element activates a wide range of enzyme systems and, as such, controls a large number of physiological functions: water economy through various mechanisms, including the proper regulation of stomatal opening and closing; photosynthesis,

light and dark respiration, by influencing chloroplast formation; carbohydrate and nitrogen metabolism, resulting in greater leaf area and a delay in leaf senescence; transport of photosynthates and minerals; promotion of growth of young meristems; symbiotic nitrogen fixation; Bailey (1983) reported that alfalfa treated with potassium fertilizer had higher protein content and improved winter-hardiness (Table 3 and 4).

Broadcast application of potassium on established alfalfa is effective, and recovery of essentially all topdressed potassium on established stands has been reported (Bailey, 1983). However, the element may be applied at anytime during the growing season with good efficiency of use. This is particularly so when it is applied immediately after a harvest is taken and under an irrigation system.

Because the element plays such an important role in the physiology and metabolism of the plant, application of potassium to alfalfa may be equivalent to buying an 'insurance policy'. This is particularly true in Western Canada where growing season conditions are quite variable and never "normal" or "average".

Sulphur: This element is generally referred to as 'The Fourth Major Nutrient'. It is an integral part of plant proteins, enzymes and vitamins. Studies have shown that the element is associated with enzyme systems that are responsible for efficient symbiotic nitrogen fixation. Further, the nitrogen and sulphur nutrition of crops are closely linked since both nutrients are required for protein synthesis. Plant protein contain about 10% sulphur and 17% nitrogen. Bailey (1984) reported that there was a close relationship between the nitrogen and sulphur nutrition of alfalfa. He found that for optimum forage yield the ratio of total nitrogen to total sulphur in the plant was 14. He also reported that for maximum yield of forage the concentration of sulphur in the herbage at full bud

should be in excess of 0.20%. He found that the application of sulphur not only increased herbage yield but also increased herbage protein (Table 5).

The soils on which sulphur deficiency is likely to occur include well drained sandy soils and grey luvisols (grey wooded) soils from which the sulphur has been leached. In recent years, however, because of reduced sulphur impurities in commercial fertilizers, and a greater depletion of soil sulphur reserves by higher yielding crop cultivars, symptoms of sulphur deficiency are becoming more common. To correct these problems sulphur fertilizer is recommended. Sulphur recommendation is based on the element being applied in the sulphate (SO_4) form since it is the only form readily available to plants. Sulphur in the elemental form as it occurs in some high analysis sulphur fertilizers must be converted to the sulphate form to be taken up by crops. Thus when the applied sulphur is intended for crop use in the year of application the sulphate forms should be used. However, for alfalfa, a perennial, elemental sulphur is a good and cheap source, provided it is recognized that the product must be applied at least one year in advance of its intended use.

Micronutrients: Very little research has been done to assess the micronutrient needs of alfalfa. However, researchers recognize the important physiological and metabolic role they play in plant nutrition. Isolated indications of apparent response to boron, copper and manganese have been reported in Saskatchewan and Manitoba, but research has not verified these reports. It is important however, to continue to monitor forages and to investigate claims of micronutrient problems. These elements although required by plants in very small quantities, when they are deficient or present in toxic quantities may cause severe economic losses to producers.

In summary optimizing alfalfa production means raising the level of management currently used for alfalfa production. It involves three planning stages: Pre-seeding Planning, Seeding/Establishment Year Management and Management of the Established Stand. Fertilizer use is only one aspect of the maximum yield equation, other parts are timeliness of operations, weed control, selection of the proper cultivars, soil and tissue testing and consultation with researchers and extension agronomists.

References

In the preparation of this paper personal communications were received and used from the following:

- Dr. S. Bittman - Agriculture Canada Research Station, Melfort, Saskatchewan.
- Dr. B.P. Goplen - Agriculture Canada Research Station, Saskatoon, Saskatchewan.
- Dr. C. Campbell - Agriculture Canada Research Station, Swift Current, Saskatchewan.
- Dr. M. Hanna - Agriculture Canada Research Station, Lethbridge, Alberta.
- Dr. R. Simons - Agriculture Canada Research Station, Brandon, Manitoba.
- Dr. J. Waddington- Agriculture Canada Research Station, Swift Current, Saskatchewan.

Information for the text was also taken from the following:

Alfalfa Science and Technology. 1972. Ed. C.H. Hanson, Pub. American Society of Agronomy, No. 15 in AGRONOMY Series. Madison, Wisconsin. U.S.A.

References (Cont'd)

Growing and Managing Alfalfa in Canada. 1982. Agriculture Canada. Publication 1705/E. Communication Branch, Agriculture Canada, Ottawa, K1A 0C7.

Other References:

Bailey, L.D. 1980. Fertilizing alfalfa forage. Manitoba Agriculture, Farm Facts. Agdex 541.

Bailey, L.D. 1980. Fertilizer management of forage crops. Mimograph Report, Agric. Canada Research Station, Brandon, Manitoba.

Bailey, L.D. 1983. Effect of potassium fertilizer and fall harvest on alfalfa grown on the eastern Canadian prairies. Can. J. Soil Sci. 63:211-219.

Bailey, L.D. 1985. The sulphur status of eastern Canadian prairie soils: Sulphur response and requirements of alfalfa, rape and barley. Can. J. Soil Sci. (In press).

Waddington, J. and Bittman, S. 1983. Bromegrass and alfalfa establishment with wheat companion crop in northwest Saskatchewan. Can. J. Plant Sci. 63:659-668.

Waddington, J. and Bittman, S. 1984. Establishment and subsequent productivity of bromegrass and alfalfa seeded with argentine rapeseed companion crop in northeastern Saskatchewan, Can. J. Plant Sci. 64:303-308.

TABLE 1. ANNUAL NUTRIENT REMOVAL BY ALFALFA FORAGE HARVESTED AT THE FULL BUD STAGE.

A. CLAY LOAM SOILS

Cut	Fertilized*						Unfertilized					
	Yield t ha ⁻¹	----kg ha ⁻¹ ----				Protein %	Yield t ha ⁻¹	----kg ha ⁻¹ ----				Protein %
		N	P	K	S			N	P	K	S	
1st	5.0	185	13	175	12	23	3.6	108	7	86	8	19
2nd	3.3	116	8	100	8	22	2.6	83	5	52	6	16
3rd	3.6	122	8	90	8	21	2.6	55	5	42	6	16
Total	11.9	423	30	365	28		8.8	256	17	180	20	

Fertilizer (kg/ha⁻¹) 0 -60 P₂O₅ - 30 K₂O - 30 S

B. SANDY LOAM SOILS

1st	4.0	152	10	104	10	24	1.0	18	2	11	2	11
2nd	3.2	112	7	74	8	22	0.8	13	1	6	2	10
3rd	3.4	119	8	68	8	22	0.0	--	-	--	-	--
Total	10.6	383	25	246	26		1.8	31	3	17	4	

Fertilizer (kg/ha⁻¹) 0 - 60 P₂O₅ - 120 K₂O - 30 S

C. FERTILIZED WHEAT (Include straw and grain)

Grain Yield	N	P	K	S
2690 kg ha ⁻¹	95	14	60	12 (kg ha ⁻¹ removed).

Table 2. Effect of phosphorus fertilizer on the yield, phosphorus content and protein composition of alfalfa at the full bud stage.

Rate of P ₂ O ₅ kg ha ⁻¹	Yield forage t ha ⁻¹	Phosphorus %	Protein %
0	5.0	0.08	11.3
23	6.1	0.15	12.5
45	10.2	0.20	13.8
67	12.5	0.22	20.0
112	11.2	0.25	18.8

A. Table 3. Total alfalfa forage harvested over a 5-yr period from five soils fertilized with K.

Soils	Annual rate of K (kg/ha)				
	0	50	75	100	200
	Tonnes/ha				
Souris (50)+	9.1a	20.8a	26.8a	34.8a	41.4a
Miniota (1250)	17.3b	27.1b	32.0ab	35.1a	46.3a
Waitville (310)	23.7c	32.0b	34.8b	38.2a	49.ab
Carroll (695)	57.6e	57.4d	57.5c	58.0c	57.9cd
Newdale (972)	44.8d	51.7c	52.8c	52.6c	52.7bc

+ Numbers in parentheses represent initial exchangeable K (kg/ha).

Numbers connected by the same bar are not significant at P 0.05 (Duncan's multiple range).

a-e Numbers in a column followed by the same letter are not significant at P 0.05 (Duncan's multiple range test).

B. Soils Low to Medium in Exch. K.

Effect of Potassium Fertilizer on the Yield,
Potassium Content and Protein Content of Alfalfa.

Rate of K ₂ O kg/ha	Yield t/ha	Potassium %	Protein %
0	3.3	0.8	9.4
56	6.4	1.2	12.5
84	8.3	1.8	17.5
112	10.6	2.5	20.0
224	10.0	3.2	21.2

5 station years on three Manitoba soils.

Initial potassium levels in the soil ranged from 30 kg/ha (27 lb/acre) to 360 kg/ha (321 lb/acre).

The plots also received an annual application of 67 kg/ha (60 lb/acre P₂O₅ and 34 kg/ha (30 lb/acre) of sulphur.

Table 4. The Effect of Potassium Fertilizer in Protecting Alfalfa from Winterkill on a Sandy Loam Soil

Year	With Potassium*		Without Potassium	
	Stand Density**	Yield*** t/ha	Stand Density**	Yield*** t/ha
1970 (seeded)	--	--	--	--
1971	98	2.6	102	2.2
1972	102	3.2	90	2.5
1973	97	4.5	82	2.5
1974	98	4.2	51	1.4
1975	102	4.6	35	0.9
1976	100	4.4	15	0.5
1977	95	4.0	15	0.5

* Received an annual application of 112 kg/ha K_2O .

** Number of plants in 3 one meter row lengths taken in May and expressed as a percentage of the same count taken in the previous September.

*** First cut only.

Initial soil test: 260 kg/ha exchangeable potassium (0-15 cm).

Table 5. Effect of Sulphur Fertilizer on the Yield, Sulphur Content and Protein Content of Alfalfa.

Rate of S kg/ha	Yield t/ha	Sulphur %	Protein %
0	3.6	0.10	8.8
17	6.2	0.16	11.3
34	9.6	0.21	18.8
51	12.0	0.23	20.6
67	11.7	0.23	21.3

5 station years on a Grey Wooded soil.

Initial sulphur content of the soil was 15 kg/ha.

The plots also received an annual application of 67 kg/ha P_2O_5 and 34 kg/ha K_2O .

SESSION III

Developing Irrigated Agriculture

Chairman: J. G. Calpas



The Economics of Water Use and Development in Agriculture on the Prairies¹

Terrence S. Veeman²

Abstract

Improved water resource management is very important to agricultural development in the prairie region. Irrigation expansion, however, is not the pivotal element in an overall water-related strategy for the prairie region. The expansion of the prairie irrigation base is likely to continue, but primarily for political reasons rather than strong economic reasons. Major irrigation issues include the improvement of water use efficiency and cropping intensity within irrigation systems and the slow cautious expansion of irrigation where, as in central Saskatchewan, considerable costly infrastructure is already in place. The most important water issue to the year 2000 is the need for improved water and snow conservation in dryland agriculture. Improved dryland moisture conservation is important to prairie production and export strategy, to the reduction of summerfallow and the arrest of soil quality deterioration, and as a part of a wider set of policies to partially "drought-proof" agriculture for a much larger proportion of prairie farmers.

¹Paper prepared for presentation at the Conference on Irrigation on the Prairies, Fourth Annual Western Provincial Conference on Rationalization of Water and Soil Research and Management, Saskatoon, Saskatchewan, November 25-27, 1985. Based, in part, on an Invited Paper delivered at the 38th Annual Conference, Canadian Water Resources Association, Lethbridge, Alberta, June 1985.

²Departments of Economics and Rural Economy, University of Alberta, Edmonton.

The Economics of Water Use and Development in Agriculture on the Prairies

Introduction

The role of water in the agricultural development of the prairies raises several perplexing questions and contentious policy issues. Kenneth Boulding (1966) put it well two decades ago when he ended his ditty relating to his California water policy experiences as follows:

So studies of water, though free from aridity
Are apt to produce a good deal of turbidity.

In this paper, I propose to discuss water issues and policy for irrigated agriculture; to outline briefly the importance of water and snow management in dryland agriculture; and, finally, to examine some specific economic issues involved in irrigation expansion in central Saskatchewan.

People from the prairies realize the great importance of precipitation and weather factors to prairie agricultural production. If soil moisture levels are poor and the June rains fail to come, prairie farmers face greatly depressed levels of yield and production. This fact, however, does not automatically lead to the conclusion that irrigation or irrigation expansion is necessarily the solution to the problems of agriculture in a sub-arid or semi-arid environment.

Furthermore, we must wrestle with the paradox that while agriculture is by far the largest consumptive user of water in the prairie region, irrigated agriculture is not that large a component of prairie agriculture. For example, the agricultural sector constitutes 68 percent of overall consumptive use of water in Western Canada, 72 percent in the three prairie provinces, and as much as 96 percent in the Alberta portion of the South Saskatchewan River Basin in a dry year (Environment Canada, 1983; Alberta Environment, 1984). Contrasted to this, the irrigated crop acreage on the prairies, which does not exceed 1.5 million acres, is only 2 percent of the total prairie cultivated acreage (including summerfallow). Even in Alberta, the dominant irrigation province, only some 10 to 12 percent of the overall value of crop production is produced under irrigation. Consequently, agriculture is a vital player (though typically the marginal or low-valued user) in the overall consumptive use of water, but prairie agriculture remains predominantly a dryland sector.

The final introductory comment I wish to make is that economists judge policy issues and projects relating to the development or use of water in agriculture in terms of social, rather than private, criteria. Economists attempt to evaluate issues in terms of their joint effects on producers, consumers, and taxpayers. The two chief economic performance criteria which economists use are efficiency and equity. Economic efficiency essentially relates to the relative magnitudes of social benefits and social costs which are associated with a particular course of action or project. Equity, on the other hand, refers to the incidence of those social benefits and costs, whether that be among individuals, regions, or functional groups in society. In short, an irrigation or drainage project whose private benefits exceed its private costs may well be desired by individual farm irrigators or irrigation communities but be found socially lacking--either because its net social benefits were negative or its impact on income distribution was adverse. Many controversies in the water arena arise because of these differing perspectives.

Water Issues in Irrigated Agriculture

The current irrigation base in Western Canada is comprised of 939,000 acres actually irrigated in 1984 (out of an assessed irrigation base of 1.1 million acres) in the major irrigation districts of southern Alberta, as well as approximately 200,000 acres of private irrigation in Alberta; nearly 250,000 acres of irrigation in British Columbia (1981 Census); 174,000 acres of intensive irrigation and 105,000 acres of once-a-year irrigation in Saskatchewan in 1983; and approximately 27,000 acres of irrigation in Manitoba. The amount of water applied to this base seldom exceeds 1.5 acre-feet per acre and more commonly averages less than one acre-foot.

The barriers to irrigation expansion are primarily economic rather than physical. It is commonly thought that the irrigation base in southern Alberta could be nearly doubled to some 1.5 to 2 million acres with internal basin supplies and expanded (using only physical criteria of assessment) to some 8 million acres if interbasin transfer of waters from northern to southern Alberta occurred. Similarly, in Saskatchewan, a preliminary physical assessment of irrigation potential suggests that approximately 1.5 million hectares of new lands (3.7 million acres) are potentially irrigable (Abrahamson and Ireland, 1985).

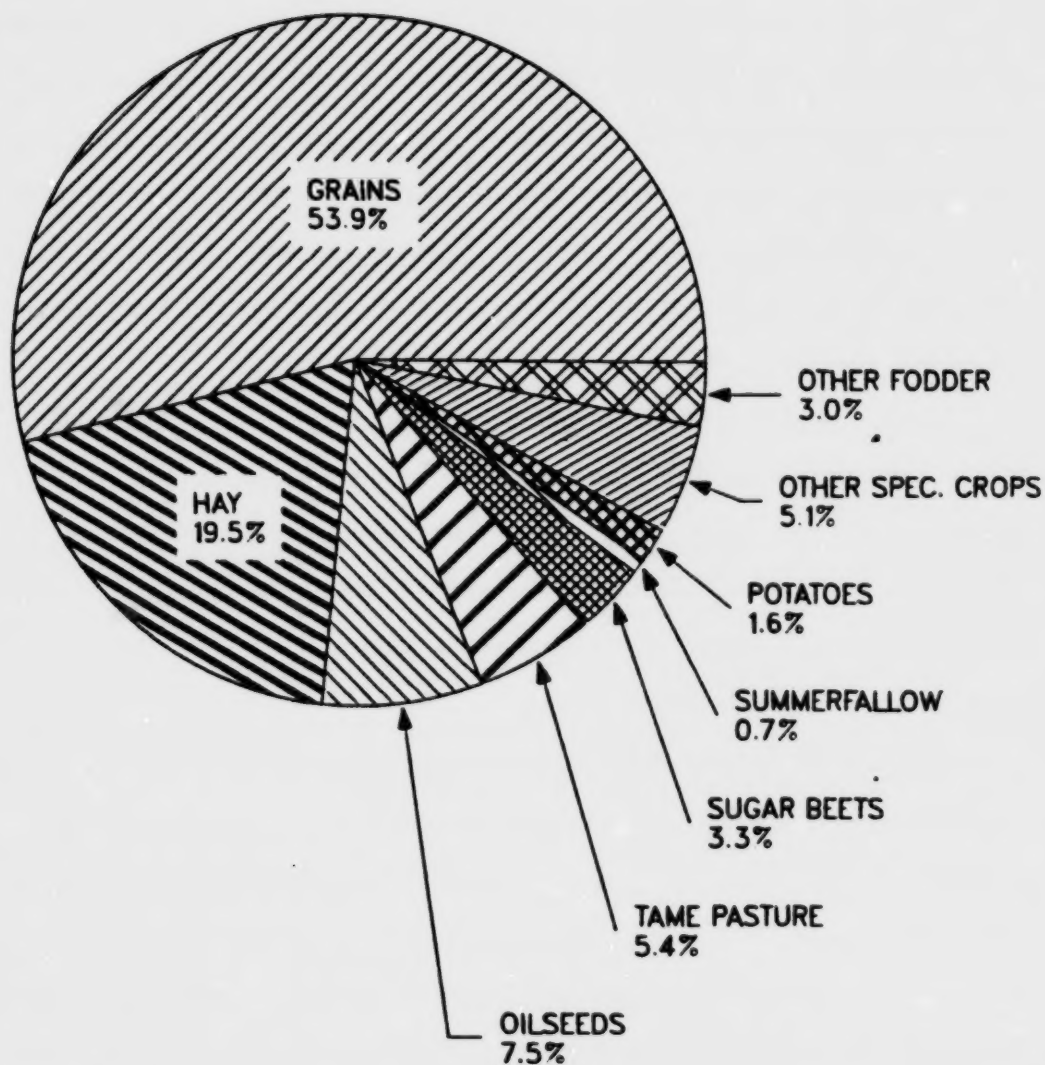
Probably the most important economic dimension of irrigation in Western Canada, especially on the prairies, arises from the fact that irrigation is focussed on relatively "low-valued" uses, chiefly grains and hay. The cropping mix for the major irrigation districts in southern Alberta in 1984 is shown graphically in Figure 1. Grains and oilseeds are produced on over 60 percent of the irrigated acreage. A welcome phenomenon which is yet to be fully documented is that soft white wheat appears to have largely displaced traditional hard red spring wheat in the irrigation districts. Soft white wheat acreage in Alberta has climbed from 149,000 acres in 1980 to 230,000 acres in 1981, 326,000 acres in 1982, 446,500 acres in 1983, and 439,000 acres in 1984 (Alberta Agriculture, personal communication). It is commonly assumed that soft white wheats are grown under irrigation. The price discount (recently about 10 percent) associated with soft white wheat is more than compensated by its yield advantages over traditional wheats grown under irrigation (75 or more bushels per acre versus 55). The switch from traditional wheats to soft white wheat on irrigated land permits the prairie region to fine-tune further the region's comparative advantage in grains.

The historical struggle in irrigated areas has been to try to increase the proportion of the irrigated cropland which is under higher-valued specialty crops. In 1984, only 10 percent of the irrigation area in southern Alberta was planted to sugar beets, potatoes, and other specialty crops. The fact that the usual 30,000 to 35,000 acres of sugar beets were not planted in Alberta in 1985 is a painful reminder of the difficulties of retaining and expanding irrigated specialty crop production on the prairies. Irrigated vegetable production on the prairies is very small and is not likely to expand greatly in the foreseeable future. A balanced perspective on the problems and prospects with respect to specialty crop production is found in the recent Environment Council of Alberta (1985) land base study. Several specialty crops grown under irrigation face considerable competition from specialty crops grown under dryland conditions, particularly in southern Manitoba.

In my judgment, the priorities for irrigated agriculture on the prairies should not be expansion of existing irrigation systems (at least where major dams and headworks are needed) but rather improving the efficiency of water use and increasing the intensity of cropping mixes on the existing systems that are in place (Veeman, 1985). Economic doubts still remain about the relative merits of

Figure 1

Irrigated Cropland In Alberta 1984



Source: Alberta Agriculture, Agriculture Statistics Yearbook 1984, forthcoming. Data courtesy of Alberta Agriculture, Statistics Branch, 1985.

irrigation expansion on the prairies when grains and forage would inevitably dominate the prospective cropping mix. The basic economic difficulty of trying to justify irrigation projects on the prairies/plains existed in the economic studies of the South Saskatchewan River Project in the 1950s and is evidenced in more recent studies in the 1970s ranging from the Garrison in North Dakota (Pheiffer, 1978) to the Oldman River in Alberta (Anderson, 1978). In the Garrison case, benefit-cost ratios, properly calculated, ranged from 0.44 to 0.77. The 1978 studies of irrigation expansion involving on-stream storage in the Oldman Basin suggested a ratio of primary benefits (excluding secondary benefits) to costs of 1.1 (Anderson, 1978). One fears that the benefit stream (in real terms) has eroded since that date, while costs have increased. Despite questionable economics, irrigation expansion has, and is, occurring, largely for political reasons. It is imperative that efforts be continued to increase the "intensity" of crop production under irrigation, so that historic and current investments in irrigation have a better pay-off.

During the extensive Oldman studies, it was generally assumed and/or concluded that the economic priorities in irrigation in Alberta should lie first with rehabilitation of the existing system, second with off-stream storage, and third with on-stream storage. One suspects, however, that the economic merits of various rehabilitation options varies considerably by site and circumstances and that we need more work in isolating the better rehabilitation options.

Irrigation Expansion in Central Saskatchewan

In central Saskatchewan, the evaluation of irrigation expansion is a special case because considerable irrigation infrastructure is already in place. Sunk investments have already been undertaken by society in providing the Gardiner Dam, the Lake Diefenbaker reservoir, and some delivery infrastructure (including a partially completed canal on the West Side from the damsite to near Conquest). For current evaluation purposes, these sunk capital costs are considered to be zero. As a consequence, the costs of irrigation expansion in this instance are substantially less than in other projects on the prairies where one is starting irrigation from scratch or greatly expanding existing infrastructure.

A major study of irrigation expansion in central Saskatchewan has just been completed for the Governments of Saskatchewan (Saskatchewan Water Corporation) and Canada (PFRA) by UMA Engineering Ltd. (1985). There is much valuable information in this study, but I wish to make several comments regarding how the results of this study should be interpreted. A key table from the UMA study is reproduced in Table 1. In this table, the benefit stream underlying the benefit/cost and net present value calculations is said to consist of "direct" benefits. It is my impression, however, that this benefit stream consists of primary (or direct) benefits as well as that portion of secondary (or indirect) benefits which is associated with forwardly linked economic activity (that is, further processing or transporting of irrigated production which, in Wantrup's terminology, are called "stemming" secondary benefits). The UMA analysts also calculate "indirect" benefits, using input-output analysis, which when added to their so-called "direct" benefits, gives considerably higher B/C ratios and net present values than shown in Table 1 (see, for example, UMA Table 6.3). What they term "indirect" benefits is really that portion of secondary (or indirect) benefits which is associated with backwardly linked economic spin-offs (for example, additional economic activity in industries supplying inputs to irrigated agriculture or what Wantrup called "induced" secondary benefits).

The problem of secondary benefits has long been a most troublesome and controversial aspect of benefit-cost studies, especially those relating to water projects (Ciriacy-Wantrup, 1955; Veeman, 1978; Gysi, 1980). Economists argue that secondary benefits can only be counted as efficiency benefits within the efficiency analysis if resources are unemployed within the provincial economy and if the spin-off activity truly represents a net gain in economic activity within the province. Prior to 1982, it was clearly improper to include secondary benefits as legitimate efficiency benefits. Today, for their inclusion, the analyst must be convinced that the unemployment of resources would be chronic over the life of the project. Moreover, all projects generate secondary impacts, so a more useful question may be how much more secondary benefits Project A yields than Project B. In general, economists remain reluctant to justify projects in terms of their secondary benefits and would prefer to adjust primary costs (especially labor costs during construction) of the project during periods of cyclical unemployment. This is not to say that secondary benefits are unimportant in project evaluation. Their

Table 1.
Economic Feasibility of Irrigation Expansion Projects in Central Saskatchewan (In Terms of
Benefit-Cost Ratios and Net Present Value Calculations) Under Three Prospective
Development Scenarios

	S C E N A R I O		
	Grain	Livestock	Aggressive
Benefit/Cost Ratios (B/C):			
Luck Lake	.8	1.4	2.2
West Side	1.5	2.6	4.5
Blackstrap	1.3	2.2	3.5
Riverhurst Reg	.6	1.0	1.6
All Projects	.9	1.4	2.3
Net Present Values (B-C) (\$ million):			
Luck Lake	-5	11	35
West Side	32	98	212
Blackstrap	2	6	13
Riverhurst Reg	-73	8	130
All Projects	-44	123	390

Source: UMA Engineering Ltd., 1985, p. 6.4.

proper role relates to the objective of regional income distribution as well as to questions of repayment and pricing (Ciriacy-Wantrup, 1955). For example, are the prospective project areas (Luck Lake, etc.) considered to be richer or poorer sub-regions in Saskatchewan?

The results in Table 1, then, appear to be based on primary benefits and some, but not all, secondary benefits. In my judgment, the grain development scenario is by far the most likely and realistic, with the aggressive (specialty crop) scenario being most unlikely. The livestock development scenario is perhaps possible, but raises the further questions of whether the red meats sector should be

expanded or contracted at the current moment and whether, if red meats production were to be expanded, that should come from investments in dryland or irrigated agriculture. One's overall impression is that irrigated grains expansion in the West Side and Blackstrap sub-regions is marginally feasible with benefit-cost ratios slightly over one (even if the suspected limited stemming secondary benefits associated with grain processing, etc. were removed).³ It would be useful to recalculate Table 1 based solely on primary benefits, eliminating the stemming secondary benefits, to see how sensitive the results are to the inclusion of the latter. The strong presumption, however, is that irrigated grains expansion is feasible (with social benefits slightly exceeding social costs), but hardly a high pay-off social investment, on the West Side. Nevertheless, there is likely sufficient justification for the government to continue once again with irrigation development on the West Side.

Water Management in Dryland Agriculture

Even if further irrigation expansion is undertaken, the fact remains that agriculture on the prairies will continue to be overwhelmingly a dryland based sector. Because limited moisture is typically a constraining factor of production under dryland prairie conditions, improved dryland moisture conservation will be critically important during the next two or three decades to increasing prairie crop production levels, as well as decreasing the variability of production.

These dryland water issues are intimately related to wider questions of production and export strategy for the prairie agricultural sector and, in particular, to the need to develop sustainable cropping systems on the prairies which involve less soil quality degradation. The best growth prospects for prairie agriculture to the end of this century lie with grains and oilseeds if the world trade in grains expands by three percent per year. An improved dryland production strategy which would both enhance production and conserve land and water resources, involves extended cropping rotations with less summerfallow (and, if possible, more legume forage), the increased use of chemical fertilizers, and the more efficient use of snow and water resources. It is hoped that new methods of snow trapping and improved methods of dryland moisture conservation might generate the valuable extra inch or two of

.....
³ It should be noted, too, that the benefit-cost methodology which was used treated associated costs of the project as a subtraction from project benefits in the numerator, rather than as an addition to project costs in the denominator. This procedure tends to bias B/C ratios slightly upwards--see Gysi (1980) and Anderson (1978).

soil moisture which has historically been saved, very inefficiently, through the practice of summerfallowing.

Furthermore, improved dryland water and snow management is a part of a wider set of policies needed to further "drought-proof" prairie agriculture. It is unrealistic, I would submit, to expect that irrigation expansion could or should play the pivotal role in an overall strategy to combat drought on the prairies. Irrigation expansion is too costly and only alleviates drought for a very small portion of prairie farmers. Policies to combat drought for the vast majority of prairie farmers must inevitably focus on non-structural solutions, including improved dryland moisture conservation and improved stabilization policy (better crop insurance and stabilization programs).

Further Water Policy Issues

In general, water management for irrigated agriculture must turn from sole reliance on supply augmentation (increasing the quantity of water available through storage and diversions) to greater emphasis on demand management. This policy re-orientation is chiefly due to the fact that the cost of developing new water supplies at the margin has considerably increased and demand management is increasingly being recognized in many nations as a considerably lower cost societal solution to water management problems. It is disappointing not to find such a policy re-orientation at all reflected in the recent planning studies conducted on the South Saskatchewan River Basin (Alberta Environment, 1984).

During the next fifteen years, Western Canadians, including irrigation farmers, must expect the types of policy initiatives in water conservation that have occurred in energy conservation during the past decade. Policy initiatives are needed in three primary areas: (1) the more effective pricing of water; (2) the specification of improved non-price rationing schemes for water during times of shortage; and (3) the reform of provincial water rights systems (Veeman, 1985).

It is most unlikely, given recent drought and the current financial difficulties of the farm sector, that any changes will occur in water pricing policy in agriculture in Alberta during the next couple of years. Nevertheless, the stage should be set for serious consideration of the introduction of volumetric metering in irrigation use and attendant per unit water charges. Water can no longer be

treated as a free good. Water pricing policy must not only address the resource cost of developing and distributing water but must also take into account opportunity cost concepts (the value of water in its best alternative use) and unpriced external effects of water supply. As Emery Castle (1983) pointed out two years ago, the great challenge for water policy in the future will be to provide signals that will lead to the consideration of water as an increasingly scarce resource.

Fears of inadequate water supplies are commonly expressed for the South Saskatchewan Basin (Foster and Sewell, 1981). However, water scarcity is not merely a matter of physical availability, but is also heavily influenced by society's economic and legal regimes for water. In short, alleged water scarcity is as much a failing of man as a short-coming of nature. In addition to considering more effective water pricing, which is apt to be introduced very slowly and incompletely in the agricultural sector, more clearly specified plans for non-price rationing should be made which permit the re-allocation of water to higher valued uses, whether that be within or outside the agricultural sector.

Finally, further efforts must be made to restructure and reform provincial systems of water rights to facilitate the transferability of water to higher-valued uses in the course of economic development. The existing systems of administrative apportionment, which typically include temporal priority aspects and which tie water to designated parcels of land, will prove too inflexible in the future. The western provinces should consider, at least on an experimental basis, a system of transferable market entitlements to water for some water uses (Randall, 1981). Such systems could facilitate the establishment of temporary rental markets for water together with the permanent sale of water rights and thereby enable the transfer of water to higher-valued use.

Conclusion

Improved water resource management is very important to agricultural development in the prairie region. Irrigation expansion, however, is not the pivotal element in an overall water-related strategy for the prairie region. The expansion of the prairie irrigation base is likely to continue, but primarily for political reasons rather than strong economic reasons. Major irrigation issues include the improvement of water use efficiency and cropping intensity within irrigation systems and the slow cautious expansion of irrigation where, as in central Saskatchewan, considerable costly infrastructure is

already in place. The most important water issue to the year 2000 is the need for improved water and snow conservation in dryland agriculture. Improved dryland moisture conservation is important to prairie production and export strategy, to the reduction of summerfallow and the arrest of soil quality deterioration, and as a part of a wider set of policies to partially "drought-proof" agriculture for a much larger proportion of prairie farmers.

References

- Alberta Environment. 1984. *Summary Report: South Saskatchewan River Basin Planning Program*. Water Resources Management Services, Planning Division.
- Anderson, Marv and Associates. 1978. *Oldman River Basin Study Phase II: Economic Analysis of Water Supply Alternatives*. A report prepared for the Oldman River Basin Study Management Committee.
- Boulding, Kenneth E. 1966. "The Feather River Anthology," *Industrial Water Engineering* 3 (December): 32-33.
- Castle, Emery N. 1983. "Water Availability: The Crisis of the Eighties?" *Canadian Water Resources Journal* 8 (Fall 1983): 57-66.
- Ciriacy-Wantrup, S.V. 1955. "Benefit-Cost Analysis and Public Resource Development," *Journal of Farm Economics* XXVII (November): 676-689.
- Environment Canaua. 1983. *Canada Water Year Book 1981-1982*. Ottawa: Supply and Services.
- Environment Council of Alberta. 1985. *Maintaining and Expanding the Agricultural Land Base in Alberta: Technical Report and Recommendations*. Edmonton: ECA, 198 pp.
- Foster, H.D. and Sewell, W.R.D. 1981. *Water: The Emerging Crisis in Canada*. Toronto: James Lorimer & Co.
- Gysi, M. 1980. "A Review of the Benefit-Cost Analysis of Two Southern Alberta Dams," *Canadian Water Resources Journal* 5 (Vol. 1): 76-86.
- Nicholaichuk, W., Dyck, F.B., and Steppuhn, H. 1984. "Snow Management for Moisture Conservation," Contributed paper to Annual Meeting of the CSAE, Winnipeg, August, 1984.
- Pheiffer, G.H. 1978. "Benefit-Cost Analysis of North Dakota's Garrison Diversion Unit: A Case Study of Conflicting Interests," *Western J. Ag. Econ.* 3: 225-232.
- Randall, A. 1981. "Property Entitlements and Pricing Policies for a Maturing Water Economy," *The Australian Journal of Agricultural Economics* 25 (December 1981): 195-200.
- UMA Engineering Ltd. 1985. "Canada/Saskatchewan Irrigation Project Appraisal Study," Volume I. Draft.
- Veeman, T.S. 1978. "Benefit-Cost Analysis Relating to Water Storage with Special Reference to the

- Oldman River Basin in Southern Alberta," *Canadian Water Resources Journal* 3 (No. 1): 41.49.
- Veeman, T.S. 1980. "The Role of Water Management in the Expansion of Prairie Grain Production: Economics and Policies." Paper presented at the Prairie Production Symposium sponsored by the Advisory Committee to the Canadian Wheat Board, Saskatoon, October, 1980.
- Veeman, T.S. 1985. "Water and Economic Growth in Western Canada." Discussion Paper No. 279 prepared for the Economic Council of Canada, 95 pp.
- Veeman, T.S. and Veeman, M.M. 1985. "Western Canadian Agriculture: Prospects, Problems, and Policy," *Canadian Public Policy* XI: Supplement on Western Canadian Economic Development (July): 301-309.

"IRRIGATION ON THE PRAIRIES"

Western Provincial Conference, Saskatoon, Saskatchewan, Nov. 25-27, 1985

GARRISON DIVERSION, THE PROCESS,

By H. M. Olson, Superintendent
Carrington Irrigation Station - NDSU

In 1958, The Sioux City Register commented: "Of all the variable things in creation, the most uncertain are: The action of a jury, the state of a woman's mind, and ...the condition of the Missouri River." If The Register were writing today in this era of the liberated woman it is highly unlikely they would make reference to the unpredictability of her mind. Nevertheless, the concern for the untamed Missouri River was real. It was either flooding or often too shallow for river commerce.

In 1889, the Director of the US Geological Survey, John Wesley Powell, addressed the North Dakota Constitutional Convention while on tour of the Northwest. He told the delegates: "Years will come of abundance and years will come of disaster, and between the two, people will become prosperous and unprosperous." He went on to say, "As members of this convention, this is what I want to say to you: In Dakota you are to depend hereafter in a great measure on the running streams. Don't let these streams get out of the possession of the people. If you fail in making a constitution in any other respect, fail not in this one. These lands have to depend on placing the water on the soil."

In 1895, the first editors of The Farmer magazine wrote: "The time will come when people of the upper Missouri River will look back and see how foolish they were to let that vast amount of water roll back to the sea last spring and carry death and destruction to the people of the South, while we suffer all the rest of the year for lack of moisture. The only way for us to change this is to tap the Missouri."

In 1902, the Reclamation Act was signed by then President Theodore Roosevelt who had experienced first hand the value of water in the northern plains by having lived and ranched in the North Dakota Badlands. The primary purpose of the Act was to set up water storage and distribution systems in the 17

western states.

In 1912, the annual report of the North Dakota State engineer had a rather interesting note. It concerned bringing water to Devils Lake. The 1911 state legislature appropriated \$650 for a study to determine the feasibility of taking spring waters from western North Dakota to Devils Lake. The study cost \$638. At that time Devils Lake was receding. It was proposed to take water from the Mouse (Souris) River near Minot. A 103-mile long canal was proposed with reservoirs near Minot on the Mouse, ^{on} the Wintering River near Karlsruhe and a reservoir on the Sheyenne River. Total cost was estimated to be \$1,663,000. The plan also envisioned irrigation of about 100,000 acres along the canal route on its way to Devils Lake.

For many years, several partial plans were advanced for development on the Missouri. The very severe drought in the "thirties" prompted the promotion of a number of schemes involving diversions from the Missouri for irrigation and restoration of Devils Lake. Two small irrigation projects, one Federal and one State sponsored, were undertaken in western North Dakota on opposite sides of the Missouri. Water resource development emphasis always has been and is now focused on the Missouri for the reason that about 96% of the surface flowing water in North Dakota is found in this stream. Yet, no real effort to control, manage or utilize this tremendous resource was initiated until after devastating floods in down stream states in 1942 and 1943. At the time, the early years of WWII, two federal agencies, the Bureau of Reclamation and the Corps of Engineers, prepared separate generalized Missouri River Basin plans designed to be comprehensive for flood control, irrigation, power, navigation and industrial uses. These plans were submitted to Congress and much debate occurred. One plan favored hydroelectric and irrigation development and the other flood control and navigation. Finally, by bringing in a third party, a Dr. H. L. Walster, then Dean of the College of Agriculture and Director of the North Dakota Agricultural Experiment Station, the two plans ^{were} melded into what became the 1944 flood control act. Known as the Pick-Sloan Plan, it called for the construction of major dams on the Missouri River to impound water to provide flood control, power generation, navigation, irrigation, fish and wildlife enhancement, municipal and industrial water and recreation benefits. The down stream states were to get relief from flooding and a stabilized flow for navigation. The upstream states were to realize

the other benefits with power revenue to fund a large share of the development costs necessary for their realization.

Since the enactment of the plan, Federal, State and local officials have been working together to implement it in stages. The first phase was the building of the present six mainstem dams by the Corps of Engineers -- one in Montana, one in North Dakota and four in South Dakota. Reservoirs created by the dams caused inundation of river bottom lands in all three states with over 550,000 acres in North Dakota alone, much of it productive farm land. Hydrogenerated power has been substantial with over \$45,000,000 in ^{Annual} revenue realized by just North and South Dakota and Minnesota. The low cost power is distributed to six states with Minnesota the largest beneficiary.

Though flood control, navigation benefits and low cost hydro power have been realized for about 30 years, very little irrigation development has taken place. The original diversion plan for irrigating lands in North Dakota required a diversion dam on the Missouri just west of ^{the} North Dakota boundary in Montana. Water was to be lifted about 104-feet into a canal near Crosby, North Dakota, which would follow the Coteau hills (escarpment) eastward to the Souris basin and beyond. Predominate soils to be irrigated (approximately 1,000,000 acres) were glacial till which were ultimately determined to be unsuited for surface or gravity irrigation because of inadequate internal drainage (permeability). As a result, the search for soils suitable for irrigation based on the newly established irrigable soils criteria shifted eastward to the drift prairies including the eastern part of the Souris River basin. This change in the area to be irrigated and other factors necessitated reauthorization of the Garrison Project in 1965. It was considered the first stage of the ultimate development. It provided for irrigating 250,000 acres; a municipal and industrial water supply for 14 towns and cities; and fish, wildlife and recreation development. It became known as the "Initial Stage of the Garrison Diversion Unit." In 1966, a master contract was executed between the Department of Interior and the Garrison Diversion Conservancy District. The latter is a legal entity established by North Dakota Law to act as the State's contracting agency with responsibility for making payments, collecting monies and operating the Project. In July 1967, construction of the principal supply works began. This included the Snake Creek pumping plant and the McClusky Canal. In 1969, the National Environmental Policy Act

was passed. It required preparation of Environmental Impact Statements (EIS) for all resource development projects by the agency responsible, in this case the Bureau of Reclamation. Shortly thereafter, the first court challenge on the adequacy of the EIS was initiated by the "Committee to Save North Dakota." The challenge was denied in US District Court in 1974 and again in 1975 upon appeal to the Court of Appeals.

In 1976, the National Audubon Society filed suit against the Department of Interior in US District Court in Washinton, DC to enjoin further construction and land acquisition on the Garrison Diversion Unit (GDU). Their complaint raised issues of the adequacy of environmental assessment of the GDU to the Fish and Wildlife Coordination Act and the Migratory Bird Treaty. As a result in 1977 the Department of Interior reached an agreement with the Audubon Society in the form of a Stipulation and Order to: (1) complete a supplementary environmental statement that describes all reasonable alternatives; (2) propose legislation to the Congress requesting authorization of one or more of those alternatives and/or reauthorization or deauthorization of the project; and (3) submit to the Congress the proposed legislation and a fish and wildlife mitigation plan. This work was accomplished and submitted to the Office of Management and Budget. The proposal was never introduced in Congress. In 1978, the Congress directed the Department of Interior to build the Garrison Project and made about \$18,000,000 available for construction. The Stipulation and Order was vacated by the District Court and the decision was appealed by the Audubon Society. The Appeals Court remanded the matter back to the District Court and the District Court Judge issued an injunction in 1981 which ordered all activities in violation of the Stipulation and Order to cease. This order was appealed and a stay was granted which permitted construction activities to resume. About 1 year later, in 1982, the Court of Appeals ruled the 1977 stipulation was invalid and remanded the case again back to District Court.

In a concurring opinion Judge MacKinnon in District Court said that the National Audubon Society "has delayed the Garrison Diversion through misuse of the National Environmental Policy Act" and "that the project should, at some point, be immune from incessant litigation." He further noted that some "organizations by a misuse of NEPA have directly caused the cost of some projects to increase by billions of dollars."

Finally in late 1982, the suit was dismissed without prejudice by the District Court

A third major lawsuit on the Project began in 1981 when the South Dakota based James River Flood Control Association alleged that the EIS was defective for reason of not adequately addressing the impacts on the James River and that the phased implementation plan for development of the Project was not authorized. The National Audubon Society provided significant assistance to the Association as a "Friend of the Court" even though still involved in the afore mentioned litigation. In December 1982, the complaint was dismissed. The ruling was appealed to the Court of Appeals which remanded the case back to the District Court. The case was dismissed in early 1985.

Further problems developed and continued due to anti-Garrison lobbying against funding for the Project in Congress. As a result, a compromise between the North Dakota Congressional delegation and the National Audubon Society was reached with the creation of a twelve-member commission appointed by the Secretary of Interior. It called for a complete stoppage on construction as of October 1, 1984 until the Commission report was complete. Their final report was issued on December 20, 1984. Recommendations were:

- 1) Provide municipal, rural and industrial water service to as many as 130 town and rural areas
- 2) Irrigate only 130,940 acres in North Dakota
- 3) Treat all water that might accrue to Hudson Bay drainage to avoid biota transfer
- 4) Include measures for mitigation and enhancement of wetlands and recreation

In the meantime, construction has resumed with the \$41,000,000 previously appropriated for fiscal 1985. The President has recommended \$41,300,000 for 1986.

Though the Audubon Society had agreed that they would abide by the Commission's recommendation, they disagree with the proponents of the project in the interpretation of the Commission report. Efforts to negotiate differences have been unsuccessful to this time. A re-authorization bill for the project based on the Commission report has been introduced. If it is not passed by March 31, 1986, the construction funds for 1986 will be lost.

In addition to the above problems, it is necessary to mention that in 1973 Canada raised questions about the impact of the Project on Canada's water resources and its potential for violating the provisions of the 1909 Boundary Waters Treaty. Following an exchange of diplomatic notes and consultations between our two governments, the matter was referred to the International Joint Commission (IJC). In 1975, the Commission established the International Garrison Diversion Study Board which undertook a detailed technical evaluation of the project and made a number of recommendations for modification of various features. The IJC adopted the Study Board's recommendations in part and added some of its own based on less than what some Study Board members could consider substantial fact.

Congress then passed a resolution in 1978 which directed that construction of the authorized project should proceed consistent with 1909 treaty provisions and consultations should expeditiously be undertaken with Canada. After considerable political maneuvering and posturing, it was agreed in 1983 that the governments of Canada, US, North Dakota and the Province of Manitoba would establish a technical committee to examine Canada's technical concerns with the Garrison Project.

And, there have been other problems too. The 1965 re-authorized project for the 250,000 acres of first stage development provided for a 146,530 acre wildlife mitigation and enhancement plan. It included 36 major areas averaging 3,900 acres in size located along the principal supply works and drains. The emphasis was to provide a water supply to existing wetlands through project canals, drains and water delivery systems.

Ten years later the US Fish and Wildlife service decided that the authorized plan was not supportable and proposed a major change. Their new plan emphasized the restoration of drained wetlands that relied on a natural water supply. This involved 250 to 300 acre tracts to be scattered throughout the 25 counties of the Conservancy District. In 1980, a study group was established to formulate new approaches to mitigation for the project. A stalemate resulted and continued until 1982 when Secretary of Interior Watt and Governor Olson of North Dakota formed a Federal-State Committee that was directed to prepare a mitigation and enhancement plan that was consistent with all legal requirements, biologically sound and acceptable to North Dakota. In December

1982, the committee published its plans for the first 85,000 acres of the project. Since then the Bureau of Reclamation has received proposals from 200 willing sellers offering more than 100,000 acres for wildlife purposes.

It is obvious from what I have mentioned that the Garrison Project has become extremely complex. It has been faced with an abundance of political, legal, international and technical issues. I am sure no other proposed government multi-purpose water resource development project has ever been confronted with similar problems. It seems that priorities at the congressional level are established in large measure by lobbying efforts of such groups as the National Audubon Society. They appear to control the leverage that will influence the project's ultimate development or demise.

However, in the interim between the 1965 re-authorization and now, despite all the problems, considerable construction has taken place. Currently, the Snake Creek Pumping Plant, the McClusky Canal and the Wintering Dam, which is necessary to the creation of the Lone Tree Reservoir, are complete. In addition, the Oakes Pumping Plant, the pipeline delivery system and the drainage complex for the 5,000 acre test site is virtually complete. Originally it was intended to draw irrigation water from the Jamestown reservoir storage in 1986 with plans for the principal supply works to be complete in 1987. This is not likely to happen now for reason of the Commission Study which recommended by-passing the Lone Tree Reservoir with a Sykeston Canal which is yet to be designed. Other features of the principal supply works including sections of the New Rockford Canal are completed or under construction.

The problems experienced with the development of the Garrison Project suggest this as a method of how not to build a publicly funded irrigation project. Though the project was authorized over 40 years ago and even though North Dakota has given up over 1/2 million acres of prime river bottom land for water storage behind the Garrison and Oahe dams, less than one percent of the irrigation benefits promised and authorized exist in the state today. Of 10 million acres under irrigation from Federal Reclamation in the seventeen western states only 7,000 acres exists in North Dakota as a part of the Yellowstone Project. Former Governor Allen Olson addressing the 1984 annual convention of the National Water Resources Association in Tulsa stated, "One of the ironies of the situation is that while North Dakota has very little

irrigation we continue to carry out what is probably the most comprehensive program of irrigation studies in the nation."

I am sure the Governor's statement referred to the many interactions that have occurred over time between the Bureau of Reclamation and various state agencies. The State Engineer's office, the North Dakota Fish and Game Department and several departments of the North Dakota State University and State Agricultural Experiment Station have had very close ties with the Bureau of Reclamation in an attempt to build a sophisticated and functional project that is well organized and environmentally and economically sound.

For those of us, and there are many both Federal and State employees, who have spent a major portion of our professional lives working directly on the project and/or related features feel it most unfortunate that outside influences often uninformed on the specifics of the project plans have come to dominate decision making. The annual economic loss to North Dakota as a result of failing to build the 250,000 acre first phase as planned has been calculated by North Dakota State University economists to be \$153 million in gross business volume and \$50 million in personal income. In addition, the annual agricultural income losses due to the inundation of over 500,000 acres for reservoir storage have been calculated to be \$131,000,000 in gross business volume and \$45,000,000 in personal income. These combined annual losses (over a quarter billion dollars) are very substantial and the cause for much concern by many in our state. Recent surveys to identify public support for the project within North Dakota usually show over 70% in favor. North Dakotans recognize the value of water and are still hoping there will be development that will allow realization of economic benefits of this water resource to which the state feels rightfully entitled.

IRRIGATION - THE OPTION FOR ECONOMIC DEVELOPMENT

BY DR. H. M. HILL, DIRECTOR GENERAL
PRAIRIE FARM REHABILITATION ADMINISTRATION
AGRICULTURE CANADA

TO THE
FOURTH ANNUAL
WESTERN PROVINCIAL CONFERENCE
RATIONALIZATION OF WATER AND
SOIL RESEARCH AND MANAGEMENT
"IRRIGATION ON THE PRAIRIES"

November 27, 1985

IRRIGATION - THE OPTION FOR ECONOMIC DEVELOPMENT

DR. H. M. HILL

DIRECTOR GENERAL, PFRA

ABSTRACT

The paper reviews several agro-climatic and economic factors which help shape the pattern of past and potential irrigation development on the Prairies. On the basis of historic trends and recent studies, the relationship of irrigation with economic development is reviewed. Some of the challenges confronting irrigation in the semi-arid area of the prairies are identified. The paper concludes that successful irrigation development will likely continue to require a long term, comprehensive, integrated approach involving farming communities, the private sector and governments.

IRRIGATION - THE OPTION FOR ECONOMIC DEVELOPMENT

by Dr. H. M. Hill, Director General
Prairie Farm Rehabilitation Administration
Agriculture Canada

I welcome the opportunity to participate in this important conference and to address the relationship between irrigation and economic development on the Prairies. I plan to review some of the characteristics of the prairie agro-climatic and economic setting. I will identify what I think are some of the key challenges facing irrigation on the prairies and what some of the likely ingredients of successful irrigation development may be.

My comments are those of the Prairie Farm Rehabilitation Administration, as a federal agency with fifty years of prairie soil and water resource conservation and development experience. I will share with you some of the lessons we think the organization has learned from practical program implementation and water project development while working in co-operation with many others. My comments should not be interpreted as reflecting any particular federal policy position.

The 1984 and 1985 droughts have demonstrated that the adoption of soil and water conservation farm practices and the development of thousands of water supply projects throughout the prairies have helped to partially drought proof the region. However, it is evident that much work remains unfinished and that irrigation has had and will continue to have an important role to play on the Prairies.

AGRO-CLIMATIC CHARACTERISTICS

The agro-climatic characteristics of the region tend to determine the direction and geographic scope of existing and potential irrigation development. On average, prairie climatic conditions make it an excellent region for the production of cereal, oilseed, forage and some specialty crops. Nevertheless, the climate is semi-arid and the climatic history is one of alternating dry and wet periods resulting in high variability in water supplies. The uncertainty of prairie weather is further compounded by the possibility of climate change. A few figures will help illustrate some of these agro-climatic characteristics.



FIGURE 1 - MAJOR PRAIRIE SOIL ZONES

The major prairie soil zones are a direct result of the cumulative effect of climate and the resultant vegetation since the last glacier. Figure 1 depicts the zonation of soils into the Brown, Dark Brown, Black and Luvisolic groups. The viability and usefulness of irrigation to Prairie agriculture is also intimately associated with climate. Thus the soil zones provide a first approximation of those areas where drought and variability of precipitation provides an impetus to developing irrigated agriculture.

The Brown soil zone is the most moisture deficient region with wide variations in crop yields and a high susceptibility to severe drought. The Dark Brown soils are somewhat less arid and also less subject to severe drought. The Black soil zone reflects areas of much better moisture conditions and productivity. Severe droughts are rarely experienced. The Luvisolic soils represent transitional areas of parkland and forest where moisture conditions are good but vegetation and other climatic factors impinge upon soil formation and productivity.

Figure 2 shows the general distribution of heat units across the Prairies. Heat units are a cumulative measure of heat available for growth and are highest around Medicine Hat and Winnipeg, lowest in the north and medium in the south.

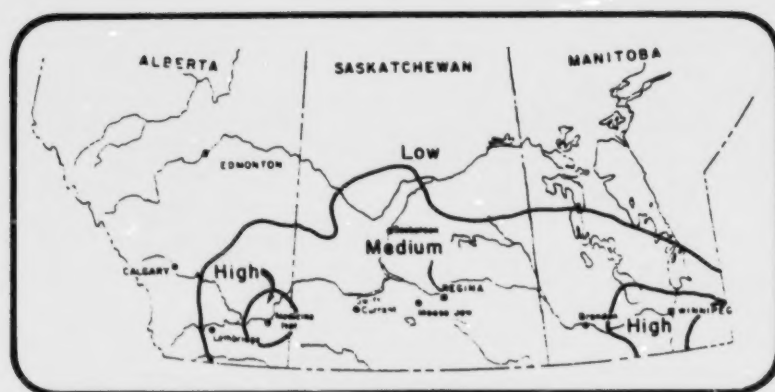


FIGURE 2 - PRAIRIE HEAT UNITS

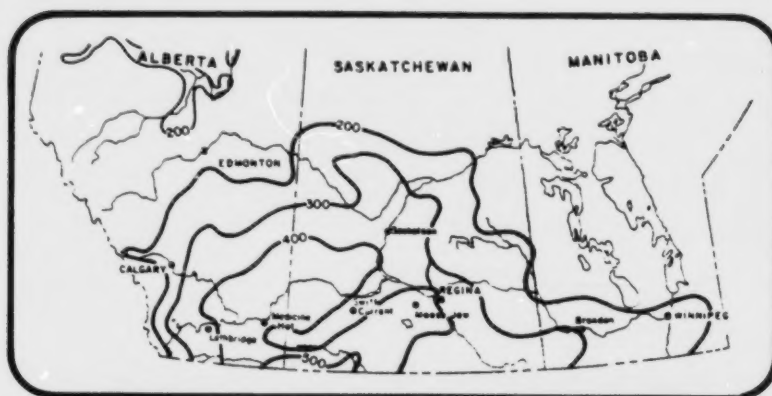


FIGURE 3 - GENERALIZED WATER DEFICIT (mm)

The availability of water for plant growth is described in general terms in Figure 3. The water deficit is the amount of additional water needed for optimum growth and ranges from in excess of 500 millimetres in the south, to between 200 and 300 millimetres, further north.

The dryland crop production pattern presented in Figure 4 reflects the shortage of water for plant growth. When wheat yields are determined on an average basis accounting for summerfallow, they are significantly lower in southern

Saskatchewan and southeastern Alberta than elsewhere in the Prairies. Dryland wheat yields average less than 15 bushels per cultivated acre in the south to over 30 bushels further north.

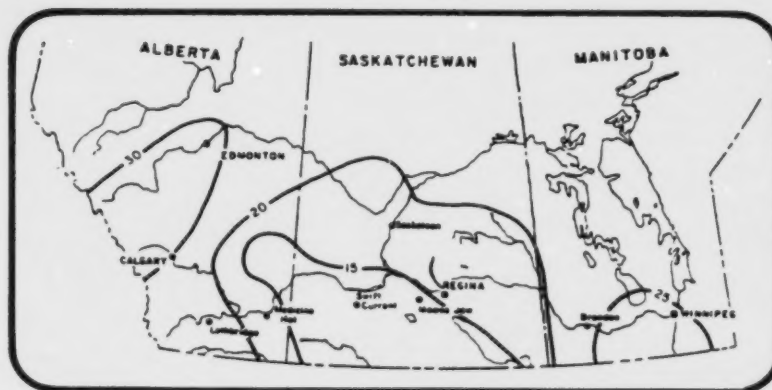


FIGURE 4 - GENERALIZED DRYLAND PRODUCTION
(wheat yields adjusted for summerfallow)

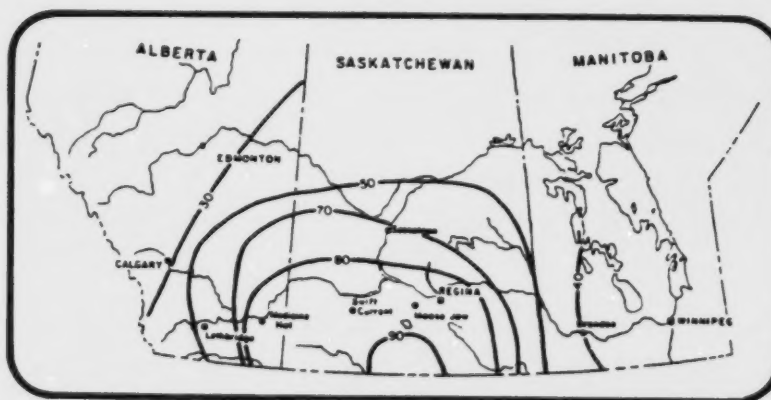


FIGURE 5 - PREDOMINANCE OF WHEAT PRODUCTION
(% of cropped area in wheat)

It is well known that the prairies have a strong dependence on wheat and opportunities for diversification vary considerably. Greater diversification exists in the more moist areas of Manitoba with higher heat units. Less diversification exists where moisture is a more limiting factor. Figure 5 shows the dependence on wheat production in the south-central region of the Prairies. In

southern Saskatchewan wheat represents 90 percent of total production, whereas part of Alberta and all of Manitoba depend on wheat for only about 50 percent of production.

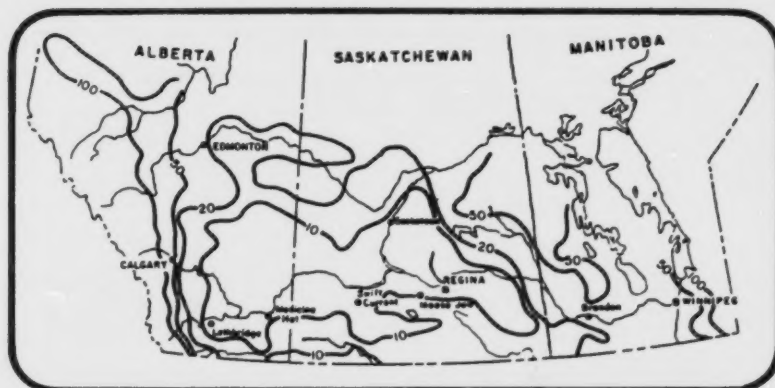


FIGURE 6 - MEDIAN ANNUAL RUNOFF (dam³/km²)

Excluding the mountain and foothill region, precipitation ranges from an annual mean of more than 20 inches at the eastern and western limits of the prairies to less than 12 inches in the central areas. On average, evaporation is greater than precipitation and the region varies from semi-arid in the centre to sub-humid at the edges. However, as most of the precipitation occurs during the relatively short growing season, dryland farming is possible in most years. Median annual runoff, as a proxy for locally available water, is presented in Figure 6.

The major irrigation projects developed to date with assured supply are shown in Figure 7. These districts use water supplied from mountain snowmelt. Numerous smaller districts, along with group and individual irrigation projects dot the prairies. However, many of these do not have an assured supply of water.

Figure 8 summarizes the various characteristics of prairie land, water and climate. The areas delineated show certain general characteristics although there are variations within the areas.

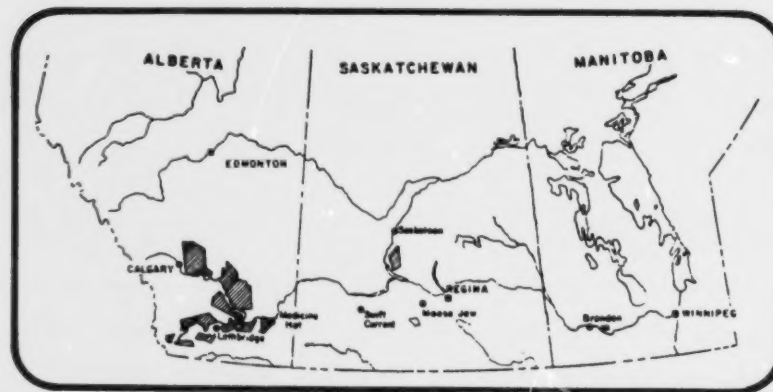


FIGURE 7 - IRRIGATION PROJECTS WITH ASSURED WATER

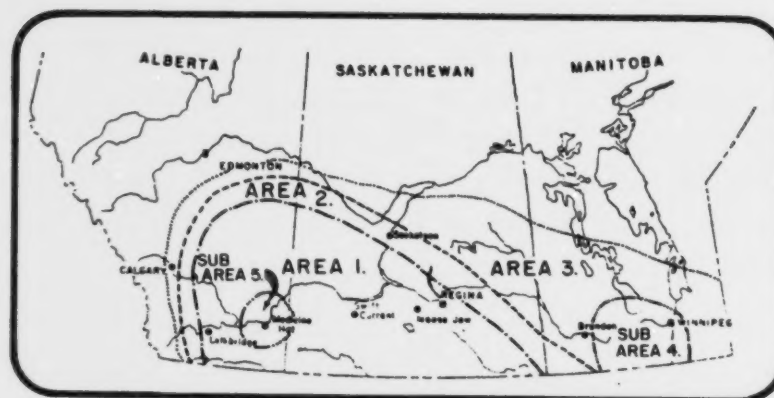


FIGURE 8 - AREAS OF GENERALLY SIMILAR AGRICULTURAL CONDITIONS

Area 1, is characterized by low annual precipitation, a relatively long growing season and adequate heat units. This area is highly drought prone and wheat is generally the major crop grown. Water supplies of prairie streams are generally fully allocated but water could be made available from mountain fed streams.

Area 3, is an area of normally sufficient annual precipitation but the growing season is shorter along with lower heat units. Water supplies from prairie streams may still be available. There is also a greater diversity of crops grown here.

Areas 4 and 5, are similar to Areas 3 and 1 except the heat units are much higher and provide for a higher level of diversification. Area 2 is a transition area.

AGRO-ECONOMIC CONSIDERATIONS

In an economic context the development and utilization of water on the prairies can be measured against the attainment of Canadian economic goals of full employment, stability, growth and international competitiveness. The prairies and irrigated agriculture can contribute to attainment of these economic goals through export expansion and import replacement strategies.

Agriculture is extremely important to Canadians. Consumers enjoy one of the lowest cost, highest quality, diverse and abundant supplies of food in the world. Agriculture and food accounts for almost a sixth of Canadian economic activity and employs nearly one of every five working Canadians. In 1981 the gross value added to the economy by agriculture was \$10.2 billion. In recent years, Canada's surplus in agricultural trade has contributed more than half the nation's total merchandise trade surplus.

At the same time, agriculture, in general, currently faces relatively low and unstable commodity prices, rising costs of production, high real interest rates and uncertain short-term market prospects. These factors affect both dryland and irrigation production.

In addition, the lack of a stable supply of water of suitable quality is a constraint to economic development on the prairies, and removal of the constraint is fundamental to attainment of economic potential in several sectors, including agriculture. Simultaneously, the construction and development associated with improving the stability of prairie water supplies for agriculture and other uses could contribute both directly and indirectly to Canadian economic goals.

IRRIGATION DEVELOPMENT OPPORTUNITIES

Irrigation development within the prairie region is currently estimated by PFRA to be about 543 thousand hectares of which about 80 percent is in Alberta, 18 percent in Saskatchewan and the remainder in Manitoba. About 70 percent of the

area has a firm supply of water, with the remainder relying on more variable spring runoff and local storage sources.

According to PFRA calculations, based on 1981 data, irrigated agriculture utilizes about 1.4 percent of the prairie improved land base; generates about 3.5 percent of prairie farm cash receipts; and produces about 6.0 percent of prairie net farm income. The economic importance of irrigation is, of course, proportionately greater in regions, such as southern Alberta, where there has been more intensive irrigation development.

There are several ways that irrigation contributes to economic development including the following:

Improved Efficiency

Over the past 35 years there has been a significant change in the method of irrigation from four percent sprinkler in 1950 to nearly 70 percent today. Technical innovations such as sprinkler irrigation and the centre pivot help make irrigation more efficient in the use of both water and labour. New low pressure sprinkler heads are reducing energy requirements and reducing water use through evaporation. More emphasis is being placed on the use of facilities and equipment to optimize water use. Computer scheduling is becoming more common as a means of utilizing water more efficiently. All of these innovations come at a cost, however, and the costs must be weighed against the benefits to be gained both on farm and to society.

Nevertheless, there are opportunities associated with increased efficiency, productivity and diversification on existing projects. To facilitate these developments, PFRA is working with Saskatchewan Agriculture, the Saskatchewan Water Corporation, the University of Saskatchewan and Agriculture Canada Research Branch to re-orient the work of the PFRA Outlook Demonstration Farm towards a centre of excellence in irrigation research, development and technology transfer.

Local Irrigation

In each of the three prairie provinces, reconnaissance type soil surveys have identified large areas as having soils suitable for irrigation in addition to

those areas presently being irrigated. Possibilities for group and individual schemes exist in many local areas from local water sources although opportunities have been more or less realized in the driest zones.

Larger Group Irrigation

There is considerable potential for major increases in irrigation from existing large reservoirs and from the development of new storage structures. In Alberta, additional acreage could be realized with projects on the Milk, Bow and Oldman river systems, by increasing irrigated lands in existing irrigation districts and by adding areas in east-central and southeastern Alberta. In Saskatchewan, additional acreage could be added through use of Lake Diefenbaker and the Saskatchewan, Qu'Appelle, Souris and Wood River systems. A major physical requirement for some of these types of projects is the construction of control structures and facilities to move water from the river valleys to the irrigable land.

Multiple Purpose Water Supply Systems

History shows that most major irrigation projects are part of multipurpose water supply schemes. They may supply water for recreation, municipal, wildlife and hydro uses, as examples, in addition to irrigation. Such multipurpose water supply development projects require long lead times for planning, promotion, design, financing and construction. Because of the long lag time between construction and the realization of multiple benefits, special economic evaluation issues are raised. Commonly, investments must be made at least a generation before many benefits are realized.

In view of the long-term and potentially multiple nature of the benefits, such projects should be designed, where practical, with a degree of flexibility to accommodate actual uses at variance with estimated uses, or uses not foreseen at all.

In recent studies conducted in Alberta and Saskatchewan, it was concluded that 15-20 percent of the total benefits of irrigation go to the farmer with the rest going to society. The benefits to the rest of society come from

additional economic activity and employment beyond the farm gate which directly depend upon the irrigation activity.

It is recognized that concurrent with project development, there is a need for further research on outstanding issues related to the economic viability, the environmental impact, the inter-relationship with other water demands and the efficiency of irrigation water use. There has been some criticism about the economics of past irrigation developments. Traditional criteria for evaluating the benefits of such projects may have been based on too narrow a definition of benefits for too short a time horizon. Many of the irrigation projects developed in the 1940s, 1950s and 1960s are only now showing their true worth in terms of employment, economic activity and multiple uses.

Methodology for economic evaluation of irrigation projects is in a state of evolution. Because the farm direct benefits are a small portion of total benefits, many projects only become feasible when the other beneficiaries contribute to the cost. Because these benefits are diverse and often difficult to assess, they have traditionally been carried by governments, such as through the 86-14 percent cost formula in Alberta. There are clearly several schools of thought and it would be helpful if economists could address the evaluation issues in a practical, consistent and integrated manner.

It should be recognized that irrigation farming often requires decades to develop the necessary financial infrastructure, to experiment and develop the best crops, and to understand the characteristics of the particular water supply, climate and markets.

We have learned that successful irrigation requires the deployment of a range of experts to deal with the various complexities of irrigation. The team consists of experts such as farmers, engineers, agronomists, soil scientists, environmentalists, economists, hydrologists, meteorologists, researchers, livestock specialists, extension specialists, consultants and politicians at all levels of government. Multilevel and multidiscipline cooperation and integration of effort has been a hallmark of prairie irrigation development and I expect will be critical to successful future development. Because irrigation debate sometimes seems to take on a tone of "religious fervor", extra effort

needs to be exerted to ensure that discussions are objective, professional and factual.

In summary, some of the key challenges facing the irrigation sector on the prairies, I think, are as follows:

- to contribute to the process of ongoing thoughtful, well conceived water resource conservation and development;
- to operate existing irrigation projects at optimum efficiency;
- to advance comprehensive, coordinated irrigation, research, planning and development involving multilevel and multidiscipline cooperation, including farmers and the private sector.
- to develop efficient, flexible multipurpose water supply infrastructure facilities for future uses;
- to develop on-farm and group irrigation projects that are sound from engineering, economic, agronomic, environmental and resource management perspectives;
- to apply practical methodology and criteria for evaluating and fairly comparing irrigation with other options.
- to continue to better understand and define the role of irrigation in rural community and regional economic development;
- to maximize the value-added and agricultural processing activities associated with irrigation development in keeping with long-run market opportunities;
- to recognize and address real funding and resource constraints at all levels of government and to consider innovative financing options; and
- to address irrigation farm management skills, adoption rates, farm financing needs, marketing, research and extension programming requirements.

In conclusion I think it is evident these are important and exciting challenges. Irrigation is not for everyone by inclination, resource base or climate; but where the circumstances are right, it is, and can be, a real opportunity for some farmers, some communities and some regions - it can be a unique opportunity to contribute to local and prairie regional economic development.

THE PEARSE INQUIRY AND PRAIRIE IRRIGATION¹

Frank Quinn²

ABSTRACT

The final report of the Inquiry on Federal Water Policy encompasses a wide range of policy issues which relate to the nature and pace of water utilization across Canada. Recommendations in two related areas, however, may have an important bearing on federal support for irrigation expansion on the Prairies. The Inquiry argued that charges to water users should reflect the cost of providing them with the benefits they receive; and that comprehensive and consistent criteria should be adopted for evaluating water projects in which the federal government participates. This paper explores the proposed scope of these practices and their implications for continued irrigation development.

The purpose of this paper is to draw to your attention those recommendations in the final report of the Inquiry on Federal Water Policy, or Pearse Inquiry, which relate in one way or another to irrigation development in the Prairie region. Accordingly, it will be necessary to establish the context of the Inquiry, its process and product, before focusing on pertinent recommendations.

¹ Presentation to "Irrigation on the Prairies" Conference, Fourth Annual Western Provincial Conference on Rationalization of Water and Soil Research and Management, Saskatoon, November 27, 1985.

² Inland Waters Directorate, Environment Canada, Ottawa. The author served as Director of Research for the Inquiry on Federal Water Policy and writes from his knowledge of events in that capacity, rather than from the perspective of his current position.

The Inquiry in Brief

The Inquiry on Federal Water Policy was established by the Minister of the Environment under the authority of the Canada Water Act on January 26, 1984. It was to be completed within a period of 1 1/2 years and a budget of \$1 1/2 million (and it was!).

The members appointed to the Inquiry were Peter Pearce (chairman), resource economist from the University of British Columbia; James MacLaren, formerly head of a national engineering consulting firm, from Toronto; and Françoise Bertrand, administrative dean at the Université du Québec à Montréal.

Their terms of reference required the substantiation of emerging water issues; identification of available water supplies and future demands on them; consultation with governmental bodies, public and private groups and citizens; and assessment of research expertise and needs. Basically, the Inquiry was expected to rethink, and propose improvements in, the role of the Government of Canada in water resources management.

The Inquiry proceeded by three avenues of investigation:

- 1) early and periodic consultation with all provincial and territorial governments, to confirm a focus on matters within the federal sphere of jurisdiction, and to facilitate information exchange;

- 2) public hearings across Canada, to consider the views and suggestions of all interests; the hearings attracted 200 participants, and resulted in the submission of over 300 briefs;
- 3) a research program, addressing a wide variety of issues and information needs; academics, consultants and government experts produced a total of 22 research papers for the Inquiry's deliberations.

The Inquiry published its initial report, Water Is a Mainstream Issue, in June 1984, interpreting its mandate and inviting public participation in its deliberations; and a second report, Hearing About Water, in April 1985, to sum up essential points from the hearings and submissions. The final report of the Inquiry, entitled Currents of Change, was released by the Minister of the Environment on September 30, 1985. All of the Inquiry's reports and research papers are freely available from the Enquiry Centre, Environment Canada, Ottawa K1A 0H3.

The final report includes 55 recommendations and a number of other suggestions for providing a more coherent federal water policy and administrative framework and for redirecting priorities towards future opportunities. These recommendations address major issues, such as drinking water safety, water export, interprovincial river conflicts, research support, the north, federal-provincial cooperative arrangements and federal agency coordination.

Because the majority of the Inquiry's recommendations are addressed to the federal government broadly, where about 20 agencies have major or minor roles in water management, and because many relate to intergovernmental programs, they require extensive review and consultation. At a meeting of the Canadian Council of Resource and Environment Ministers on October 3, all provinces and territories agreed to make a formal response to the Inquiry recommendations within 6 months. A federal interdepartmental task force has been established to prepare a response to the recommendations during the same time period. And all participants in the Inquiry's public hearings, as well as other interested parties, have been invited to comment. Following these reviews, it is expected that the Minister of the Environment will prepare a package of Inquiry-related measures upon which there is consensus for the federal Cabinet to consider for implementation. An announcement of federal response to the Inquiry recommendations is unlikely before the summer of 1986.

Recommendations Relevant to Prairie Irrigation

The issues addressed and the principles developed by the Inquiry members in their report are for the most part national in scope and applicable to all water users and interests. They are not aimed at particular uses or particular regions, such as irrigation in the Prairie region. (One exception is the north, where separate treatment is warranted by the complete extent of federal jurisdiction).

Nevertheless, some of the Inquiry's recommendations have greater import for Prairie irrigation than others, specifically those directed to user charges and to project evaluation. These are considered in the following sections, first in terms of rationale for the recommendations, then their implications for irrigation development.

User charges

Canada is no longer in its first century as a nation, establishing dominion over new territories, winning the west, or the north. Circumstances have changed from those which prevailed at the time our early farms, communities and industries drew water from the nearest lake or river. Substantial portions of available water supplies are already committed in some regions, water is no longer abundant relative to demands, and its continuing availability to users on a first come - first served basis is very much an issue.

In the face of increasing competition for water, manifested periodically and regionally in problems of shortage and contamination, governments are searching for more efficient and equitable approaches to allocating the resource among its many users. Increasing supply through further storage and diversion works has become too expensive and environmentally disruptive to rely on this means alone. Opportunities are also being explored to reduce demand by using water more efficiently. That seems

appropriate, given that Canadians are among the more profligate water users in the world, withdrawing more than twice the quantity that Europeans withdraw from nature on a per capita basis. (OECD, 1985).

An obvious way to encourage conservation and discourage waste of water is to charge a price, or a higher price, for its use. This idea enjoys growing support across the country, if the Inquiry's consultations are any indication. (Inquiry, 1985a) Support comes from professional associations, environmental and consumer groups and some provincial and municipal governments.

Pricing has advantages in addition to conservation of a scarce resource. These include reduced infrastructure costs in accordance with reduction in water demand; efficient allocation among users according to highest values from use; generation of revenue to cover distribution and treatment costs; and more equitable sharing of costs, borne by beneficiaries according to the benefits they receive from water use.

These advantages convinced Inquiry members that pricing should be an integral part of federal water policy. They proposed that it should be implemented for water use under federal jurisdiction, e.g., northern territories, national parks. More significantly, an appropriate pricing system should also be included as a condition of federal participation in water projects developed

under agreements with provincial governments. The intention is to encourage governments at all levels to enact practical water pricing schedules for all water uses and to fund water services more from user charges and less from grants and other subsidies from senior governments.

What would be the practical effect on Prairie irrigation of federal adoption of the principle that water and wastewater services should be financed to a greater degree through user charges? Presumably, it would dampen the demand for new or expanded irrigation which depends on federal assistance, thereby relieving further pressure on other water uses in a region where the resource is in scarce supply. Currently, charges for irrigation water supplied by federally-assisted projects are only about \$14 per hectare in Alberta and Saskatchewan, while the cost of delivery to the farm is about five times this amount. User charges also fall short of the value of irrigation water in terms of the enhanced value of crops produced, which ranges around \$42 per hectare annually. (Bowden and Anderson, 1985) Irrigators whose water costs are already subsidized in government-assisted projects have a significant advantage, of course, over irrigators relying on their own funds and over dryland farmers producing similar crops.

It is understandable that governments in an earlier era would support heavy investments in irrigation, like roads and railroads, in the interest of "nation-building". Today's fiscal climate is different, and governments are no longer willing to carry the major portion of the burden for such infrastructure.

Project Evaluation

The federal government has participated in numerous projects for water development in the past. Prominent examples in the Prairie region include the Red River Floodway, Gardiner Dam and St. Mary Irrigation Project. Although the pace of construction has slowed in recent years, new projects are under investigation, primarily by the Prairie Farm Rehabilitation Administration.

Certain procedures for judging the merits of public projects have been established federally, (Treasury Board, 1976) but only as loose guidelines. Different federal agencies have been left a great deal of latitude to evaluate the feasibility of flood control, salmonid enhancement, irrigation and drainage programs to suit their own purposes. The Inquiry members concluded that existing guidelines need to be interpreted more specifically for water projects and the resulting evaluation criteria applied consistently by all federal agencies. In particular, they recommended a systematic consideration of direct and indirect benefits and costs, of risks and uncertainties, and of practicable alternatives.

What does this mean for Prairie region irrigation expansion? For one thing, it means selecting a realistic range of discount rates for federal investment, e.g. 5%, 10%, 15%, not just the lowest rate a proponent agency can get away with. For another, it means including all relevant effects. It has been estimated, for

example, that for every 1/4 section of new land to be irrigated from Lake Diefenbaker, \$2,000 in hydropower revenues would be foregone. Such opportunity costs should be assessed against new irrigation development. Environmental impacts of both a possible and negative nature also must be weighed, e.g. wildlife pool benefits, irrigation return flow deterioration. It means also considering alternatives to irrigation expansion, such as improving current irrigation efficiency, and improving the productivity of dryland farming through more broadly-based soil and water conservation measures. These alternatives should be of particular interest in the Prairies, where irrigation currently accounts for 72% of total regional water consumption in a normal year, but serves only 1% of the land under cultivation.

The day has surely passed when any water use project can be evaluated in isolation from other uses of the same resource. Watershed planning provides a context for recognizing the interdependence of uses and hence for evaluating project impacts and alternatives. The Inquiry recommended that the federal government adopt the watershed as a basis for serving the interests of all water users, because it allows for these effects to be evaluated more comprehensively. It is recognized that most western provinces already administer the resource on a watershed basis.

The Inquiry noted that some federal programs for agricultural development have been designed only for certain regions or provinces. The Prairie Farm Rehabilitation Act applies, for example, only to the drought and soil-drifting of the Prairie Provinces, but irrigation is practiced in British Columbia and other provinces as well. Likewise, drainage programs have been supported in some provinces, e.g. South Nation basin in Ontario, (Canada, 1985) and not in others. The Inquiry members recommended that such programs should be available on a consistent cost-sharing basis to all provinces.

They also advised that federal support for such programs be limited to off-farm, collective or community works. On-farm assistance should be left for other levels of governments to manage.

Summing Up

The Inquiry's summary recommendation for agricultural programs encompasses the points raised in this paper and is therefore quoted in full:

The federal government should participate in irrigation and drainage programs only under cost-sharing agreements that are available to all provinces on a consistent basis. To qualify for federal support, projects should:

- i) be in the form of off-farm, collective or community works;
- ii) be subjected to comprehensive evaluation to determine all their effects in the watershed and to demonstrate that their benefits exceed costs according to benefit-cost analyses appropriate for water-related projects;

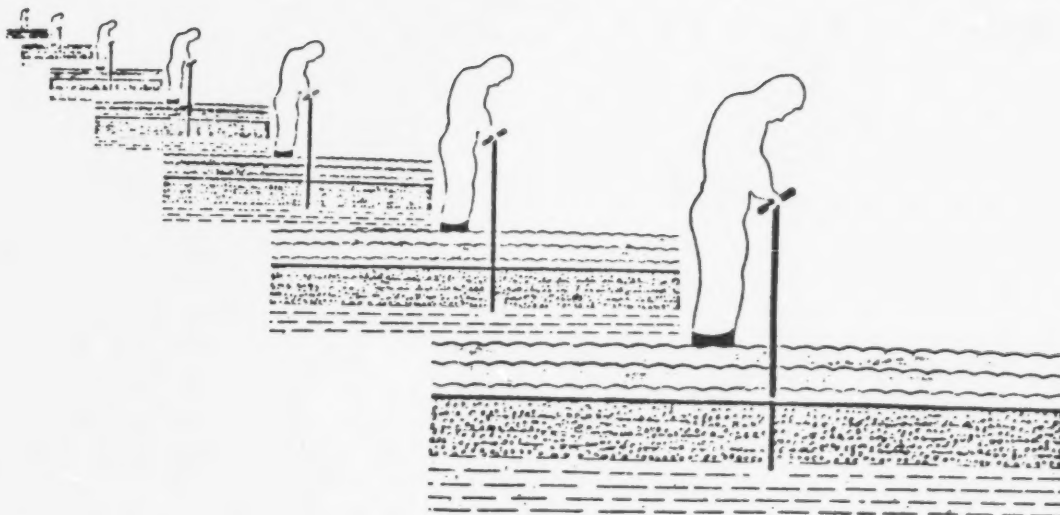
- iii) provide for charges to the direct beneficiaries that reflect the cost of providing them with the benefits they receive.

The tenor of the Inquiry's recommendations on user charges, project evaluation and agriculture generally, quite obviously runs counter to some existing practices and, if implemented, probably implies more restricted federal involvement in future irrigation development. The intent of the Inquiry is not to curtail any particular sector of the economy. It is to ensure that the federal government make best use of limited development funds and encourage the best use of limited water supplies.

REFERENCES

- Bowden, Gary and Marv Anderson. 1985. "Water and Canadian Agriculture." Research Paper No. 18, Inquiry on Federal Water Policy. Ottawa.
- Canada, Lands Directorate, Environment. 1985. "The Eastern Ontario Subsidiary Agreement Drainage Program: Impacts on the Land Resource, An Initial Evaluation". Working Paper No. 40 by Cecile, Bardecki and Snell. Ottawa.
- Inquiry on Federal Water Policy. 1984. Water Is a Mainstream Issue. Participation Paper. Ottawa.
- Inquiry on Federal Water Policy. 1985a. Hearing About Water. A Synthesis. Ottawa.
- Inquiry on Federal Water Policy. 1985b. Currents of Change. Final report of the Inquiry on Federal Water Policy. Ottawa.
- Organization for Economic Cooperation and Development. 1985. OECD Observer. No. 135 (July)
- Treasury Board Secretariat, Planning Branch. 1976. Benefit-Cost Analysis Guide. Ottawa.

FEASIBILITY OF NON-INTENSIVE IRRIGATION



NON - INTENSIVE IRRIGATION

THE CONTROLLED APPLICATION AND RELEASE OF WATER,
AT SPRING-FLOOD STAGE ONLY, THAT INCREASES STORED
SOIL MOISTURE FOR CROP USE LATER IN THE YEAR.

John Linsley, P.Ag.
Irrigation Agrologist
Irrigation Branch
Saskatchewan Agriculture
P.O. Bag 1000
Outlook, Saskatchewan SOL 2N0
(306) 867-9925

CONTENTS

	Page
Prairie Hydrology & Irrigation	1
Definition of Non-Intensive Irrigation	3
Case Studies	4
Feasibility - Physical	9
- Financial	14

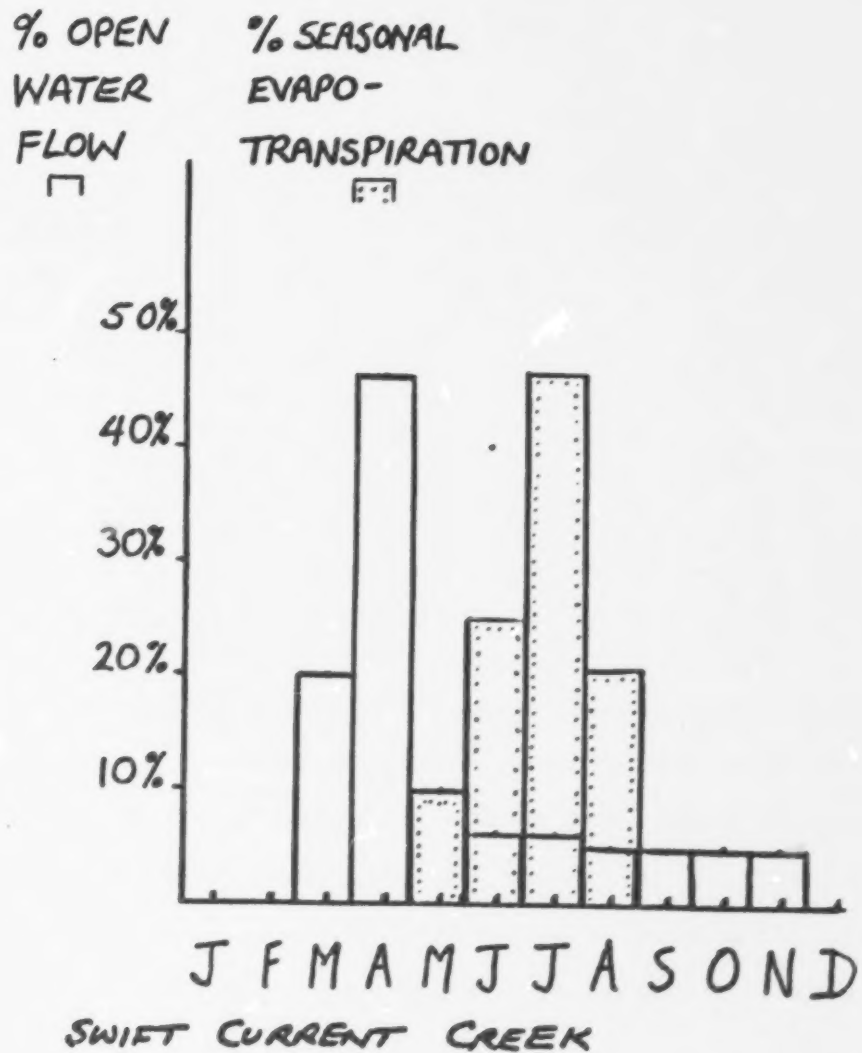
ACKNOWLEDGEMENTS

I would like to acknowledge the help of the following people, without whom the preparation of this material would not have been possible:

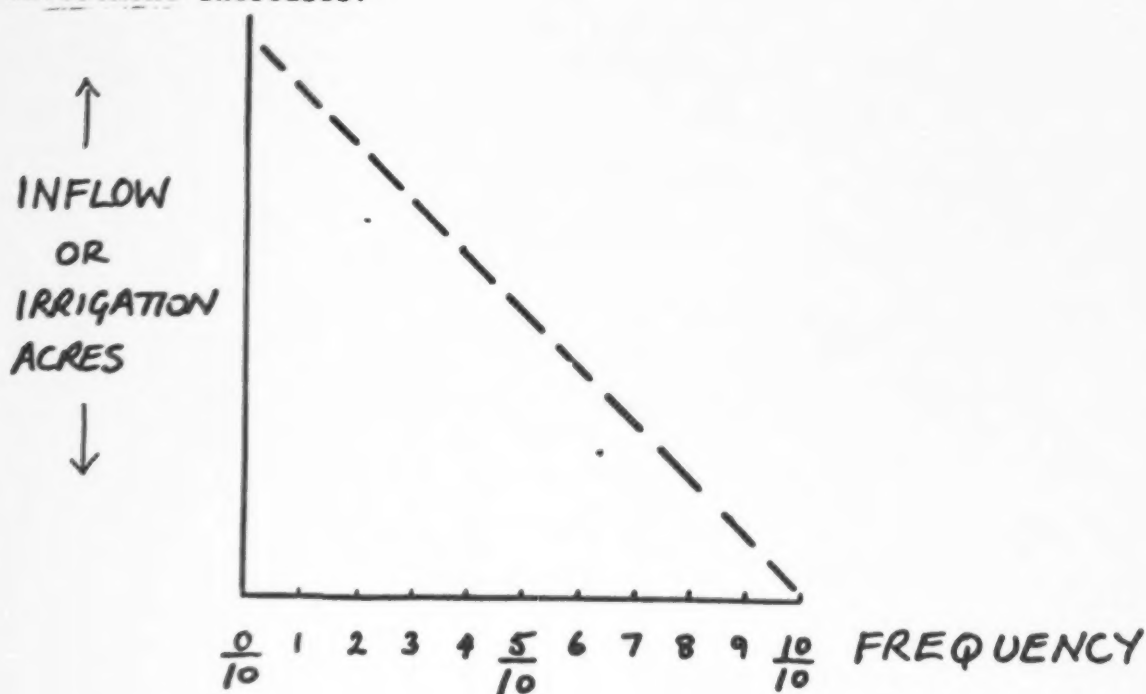
Ross Pollock	Maple Creek
Joe Schiissler	Vanguard
Norm Sharp	P.F.R.A.
Don Tutt	Rouleau
Vern Wilkins	Shaunavon

PRAIRIE HYDROLOGY AND IRRIGATION

The timing of peak stream flows and crop peak water use on the prairies does not coincide.

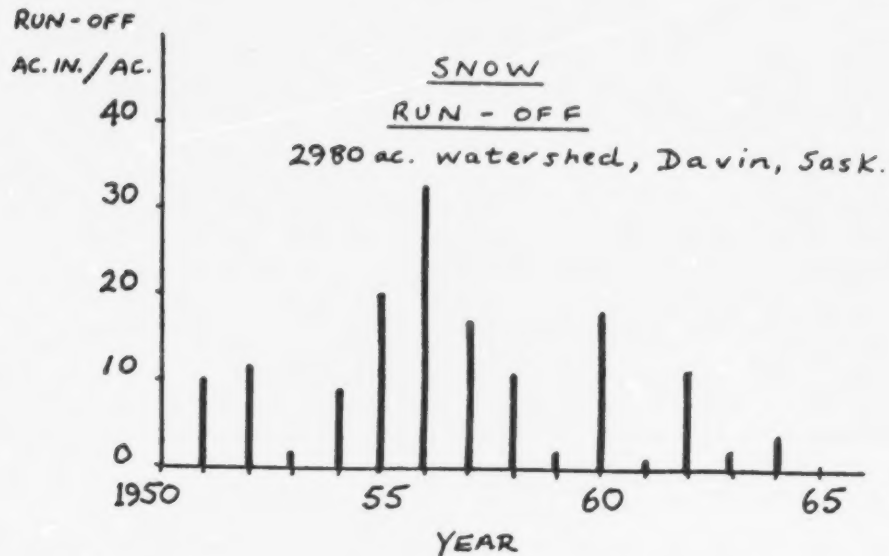


For intensive irrigation, summer flows must be sufficient for pumping or, as on most prairie streams and rivers storage must be constructed. The irrigated acreage is then determined by inflows and the number of years out of ten a water shortage can be tolerated. This number decreases as the cost of irrigation investment increases.



Early irrigators get used to no shortages, but as the number of irrigated acres increases or flows decrease, shortages will occur, and people will get mad at each other!

The majority of storage replenishment comes from the peak spring flow from snow melt runoff. The peak flow varies from year to year with significant impact on irrigation, drainage and flood control.



Source: Nicholaichuk. Trans. ASAE 1967 p. 502.

Where storage is not available or is not sufficient to completely control flows (as on many small streams, creeks and slough drainage basins) there is an abundance of water available for a short time in the spring. This either floods farmland and fills sloughs (delaying or preventing seeding), or moves downstream unused.

DEFINITION OF NON-INTENSIVE IRRIGATION

Non-intensive irrigation is a combination of drainage, flood control and water storage. It has a relatively low capital cost in most cases. It is defined here as:-

THE CONTROLLED APPLICATION AND RELEASE OF WATER, AT SPRING FLOOD STAGE ONLY, THAT INCREASES STORED SOIL MOISTURE FOR CROP USE LATER IN THE YEAR.

CASE STUDIES

A. A Farmer's Viewpoint of Agricultural Land Drainage

At the Third Annual Western Provincial Conference - Rationalization of Water and Soil Research and Management 1984 Mr. Alan Chambers of Arnes, Manitoba addressed this topic. In his area, the interlake region of Manitoba, good drainage systems are central to farm economic survival. He quoted an extreme example of 200 farmers northwest of Riverton, Manitoba who had lost all or part of their crop seven out of the last ten years.

His own farming system has adapted to cope with excess moisture from spring runoff and heavy summer rains:

1. Field drains to take water off his farm land and dump into municipal drains,
2. Increased forage crop acreage to reduce the spring work and reduce the field runoff. Forage produces well under his conditions,
3. Standing stubble in the fall to affect snow distribution and reduce runoff.

Field drains were the obvious first step for him but when the municipal drains overflowed and flooded back onto his land he realized that field drains were the obvious first step for his neighbours too! He became a Municipal Councillor and got involved with a Conservation District of several municipalities. As a result of this experience his perspective changed. "It's probably apparent by now that I have come to think in terms of water management rather than just drainage."

"On our farm we have begun installing outlet culverts on our field drains with gates on both sides; we are installing rock dams in the municipal ditches that run alongside our low value grazing areas; and 70% of our cultivated acres do have standing stubble to catch snow and reduce runoff." This quote provides a good description of non-intensive irrigation.

B. Cypress Hills

Ross from Maple Creek irrigates 300 acres of forage on his 150 cow ranch. His grandfather settled at the foot of the Cypress Hills close to the source of two streams. He developed irrigation in the 1880's and obtained one of the earlier water rights in Saskatchewan in 1906. Median annual runoff from the hills is over 15 acre feet per square mile. Ross uses a wooden diversion and contour ditches with canvas dams and all the irrigable acres have been spring flooded each year for one hundred years with the exception of 1984 when only 100 acres out of 300 received water. He averages 1 1/2 tonnes of hay per acre, sells about half his production and feeds the other half. In 1985, hay sold for over one hundred dollars per tonne, half of this cost was trucking to the Maple Creek area. The feasibility of this project does not require sophisticated economic analysis; low investment costs, reliable water supply, specialized in hay therefore only one line of equipment, produces in excess of his own requirements to allow years of shortage and provide extra income.

C. Notekeu Creek

In 1967, 13 farmers formed a Water Users' Association south of Vanguard, midway along the course of the Notekeu Creek in the Brown Soil Zone. This creek rises in the Cypress Hills but has several dams and irrigation projects upstream of Vanguard. Median annual runoff in the basin is about five acre-feet per square mile with the exception of the source in the Cypress Hills where it is three times this amount. The capital works for this 1800 acre project were cost shared 90% : 10%, Government : Farmer ratio. Joe, one of the proponents of this project, developed 200 acres in 1967 for a cost of \$2,400, this was not a big investment for him in 1967.

Initially the project flooded by gravity, but pumping was soon required as more irrigation developed and flows decreased. They recently converted their pumps to electricity for a cost of \$100,000 cost shared 85% : 15%, Government : Farmer. Joe now has 800 acres developed to spring flood irrigation and his results since 1967 can be summarized as follows:-

5 years no runoff at all and 5 years out of 10:

	Irrigated	Dryland
-----	-----	-----
Stubble	20 bu/ac	0 bu/ac
Summerfallow	35 bu/ac	20 bu/ac
1985 (no summer rain and 250 out 800 acres flooded) }	22 bu/ac	4 bu/ac
-----	-----	-----

The feasibility of this project is more susceptible to water supply and Joe's main concern is an increase in upstream irrigation development.

Initially his investment cost was low, he did some land levelling to eliminate wet spots, increased fertilizer and herbicide expenses over the years and bought a mouldboard plow to anchor the straw in the fall. He includes summerfallow on his irrigation land to protect against low runoff years.

D. Moose Jaw Creek

Don farms 1800 acres of clay land in the flood plain of the Moose Jaw Creek where spring flooding and summer drought occur in the same year. Median annual runoff for the entire drainage basin is about five acre-feet per square mile. In 1976 he developed 640 acres to backflood irrigation for a cost of \$55.00 per acre. He pumps from the creek, holds the water until it soaks in to a depth of two to three feet and then releases it to a second field before it is finally released back to the creek. Seeding operations can start one week after the release of water, given favourable weather conditions.

His results since he developed are as follows:-

Year	Acres Flooded	Yields	
		Irrigated	Dryland Wheat on SF in the area
1977	100	60 bu - Glenlea	25 bu
1978	640	40 bu - HRSW	25 bu
1979	0	10 bu - HRSW	
1980	300	3 t alfalfa	25 bu
1981	150	1 1/2 t alfalfa	
		10 bu HRSW	
1982*	640	40 bu HRSW	30 bu
1983	0	10 bu HRSW	25 bu
1984	0	10 bu HRSW	25 bu
1985	640	40 bu HRSW	15 bu

* 5" for rain followed flooding. Seeding was delayed and the irrigated crop froze in the fall.

Don's primary concern is unreliable water supply. In order to backflood and continuously crop 600 acres, as opposed to the previous 300 acres crop and 300 acres summerfallow, more machinery and fertilizer investment was required. In a year of no runoff stubble yields are poor and crop insurance, based on dryland stubble coverage, did not meet his needs (the individual coverage option is a move in the right direction as far as he is concerned.)

E. Small Water Courses and Sloughs

Vern farms in the Shaunavon area, in the Brown Soil Zone of Saskatchewan. He spent about \$700 in the mid-sixties to construct a dyke, with a control gate in it, across a small stream. He backfloods about 17 acres and in the twenty years of operation there have been only three in which all 17 did not flood. He grew an alfalfa/brome mixture which yielded about 3 1/2 to 4 t/acre. This was broken up and in 1985 he grew 50 bu/acre of oats when neighbouring dryland summerfallow was dried out. He lets water soak in to three or four feet before releasing it. VERN'S IS TYPICAL OF THE MAJORITY OF BACKFLOOD IRRIGATION PROJECTS. Small acreage, low investment, no change to farm operations but the extra production is significant.

The economics of this type of project could be analysed as follows:-

17 acres dryland hay @1 t/acre	17.0 t	
17 acres irrigated hay @3 1/2 t/acre	59.5 t	
Increased hay production	42.5 t	
Value of increase @\$60/t	\$ 2,550	
Extra Costs - Fertilizer 40lbs P 05	250	
- Haying fuel & repairs	425	
Investment cost	700	
Extra return		\$ 1,175

This type of project could be paid for in one year.

A practical and understandable method of determining the feasibility of non-intensive irrigation can be deduced from the proceeding farm examples.

PHYSICAL FEASIBILITY

1. Water Quantity

A hydrology study is done by S.W.C. or P.F.R.A. prior to development.

A water right for non-intensive irrigation is given based on median annual flow, and an assumption of how much water is stored in the soil (4", 6" or 8"). In order to flood every acre, depending upon topography and the land levelling that has been done, many times that amount of water may be required. The early non-intensive irrigators in a drainage basin and those closest to the source of runoff get used to flooding every acre, every year. However, as more acres are developed more shortages occur and the true nature of the work "median" become clear (median means in half the years water flows will exceed the value given and in half they will be less).

The implication for the farmer is that he needs to know how frequently the flow will equal the quantity he requires to cover his acreage rather than the lower quantity that his soil will store.

For those projects where pumping is necessary the duration of runoff is important. The ideal is a month of steady flow as opposed to a three day flash flood.

225 U.S. gpm is one acre-foot per 24 hour day. In order to pump 100 acre-feet onto a 50 acre project in one week of high flows in April the following pump capacity is required:-

$$\frac{100 \text{ acre-feet}}{7 \text{ days}} = 14 \text{ acre-feet per day}$$

$$225 \text{ gpm} \times 14 = 3150 \text{ gpm}$$

This calculation also applies to the pumping rate required to drain water off a piece of land.

Non-intensive irrigation land should be drainable as quickly as possible, i.e. within 24 hours. This will require land levelling to eliminate wet spots within the fields and an outlet design that will control erosion.

Consideration of "sufficient outlet" is given when granting a water right for non-intensive irrigation. This ensures that the release of water does not flood out the downstream farmer. There are many examples of non-intensive irrigation projects that have been thwarted by the downstream farmer, and rightfully so, because no attempt has been made to include him in the benefits of the project.

2. Water Quality

Water quality is usually good as it comes from snow melt runoff. The quality is checked by Saskatchewan Agriculture prior to development.

3. Topography

The cost of development increases with the more dirt that has to be moved for dikes, ditches and land levelling, and the quantity of water required to flood all the acres (versus the quantity stored in the soil) increases.

4. Soil

A deep profile of medium to heavy textured soil is required for non-intensive irrigation. Soil moisture holding capacities are as follows:-

TEXTURES AND ESTIMATED WATER RELATIONSHIPS

TEXTURE		PERCENT (%)		VOLUMES (IN)		MOISTURE (%)	
		S	CL	L	CL	%	IN
SAND	S						
LOAMY SAND	LS	10	1.68	5	0.81	5	0.84
LOAMY FINE SAND	LFS	15	2.52	7	1.18	8	1.34
SANDY LOAM	SL	18	3.02	8	1.34	10	1.48
FINE SANDY LOAM	FSL	20	3.36	9	1.51	11	1.65
VERY FINE SANDY LOAM	VL	22	3.70	10	1.68	12	2.02
SILT LOAM	SIL	22	3.70	10	1.68	12	2.02
LOAM	L	24	4.03	12	2.02	12	2.01
LOAM (HV)	L(HV)	25	4.20	13	2.14	12	2.06
CLAY LOAM	CL	26	4.37	13	2.14	13	2.23
CLAY LOAM (HV)	CL(HV)	27	4.54	14	2.35	13	2.19
SILTY CLAY LOAM	SCL	27	4.54	14	2.35	13	2.19
SILTY CLAY	SIC	32	5.36	17	2.86	15	2.52
CLAY	C	40	6.12	22	3.70	18	3.02

PER CENT (%) AND INCHES (IN) ARE EXPRESSED IN TERMS OF A 12" DEPTH. IT SHOULD BE NOTED THAT THE VALUES SHOWN ABOVE ARE FROM NUMEROUS SOURCES AND FROM FIELD WORK DONE IN THE PAST, AND WOULD SEEM TO BE REASONABLE.

LLOYD SUTHER - CHAIRMAN LUNCH

The table shows that two-feet of wet clay will store six-inches of moisture that is available to the crop. The time for this water to soak in will be approximately ten-days when frost is in the ground and drop to about four or five-days as the ground warms up.



It is important to use a soil probe to check the depth of penetration and to release the water once the desired depth of two to three-feet is reached. Over flooding will cause a saturated layer to remain in the soil after harvest and this will allow an accumulation of salts at the upper boundary of this layer. The objective is to have the crop use up all the stored moisture each year.

Soil suitability for non-intensive irrigation is checked by Saskatchewan Agriculture prior to development.

5. Crops

A. Grain

Non-intensive irrigation is an attempt to replace the need for summerfallow and provide enough stored moisture to carry a crop through the heat of July and August. Staple and Lehane compared wheat yields versus moisture use on fine, medium and coarse-textured soils during the years 1938 to 1962 (Canadian Journal of Soil Science, Volume 45, 1965). They concluded that grain yields were little influenced by the amount of moisture stored in the 0 to 6 inch and 6 to 12 inch layers at seed time, but they were increased markedly by the moisture stored below the 12 inch depth.

Their research conclusion was demonstrated by the farm examples quoted above in 1985 where, with non-intensive irrigation, yields were 22 bushels versus 4 bushels and 40 bushels versus 15 bushels on irrigated and dryland, respectively with no appreciable growing season rainfall.

It is important to anchor the straw in the fall using a disc, twisted spike or plough.

B. Forage Crops

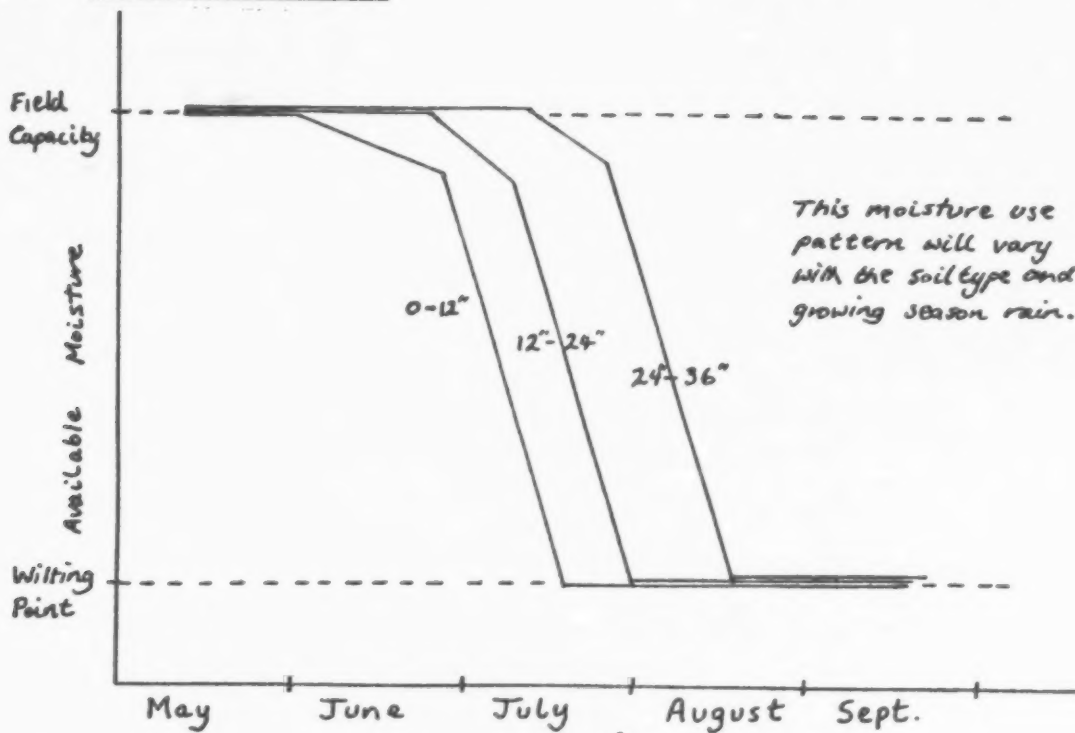
Forage crops are deep-rooted and their yields are directly related to evapotranspiration which in turn is directly related to available moisture stored in the soil.

Alfalfa has a deep root zone and can withstand seven to ten days of flooding before the frost comes out of the ground. Yields in excess of three tonnes per acre of hay can be achieved.

Grasses produce equally well but require additional Nitrogen fertilizer. Spring flooded brome grass on a project in southwest Saskatchewan averages 2 1/2 t of hay per acre with 100 pounds of Nitrogen.

Recommendations for forage crops where salinity and/or flooding occur are given in the Forage Crop Recommendations published annually by Saskatchewan Agriculture.

6. Crop Moisture Use



FINANCIAL FEASIBILITY

1. Crop Yields

The increased yields from non-intensive irrigation depends simply on whether the land is flooded or whether it remains dry. As stated above, non-intensive irrigation replaces the need to summerfallow. Therefore if land is flooded, fertilized and the weeds controlled it should produce at least the average summerfallow yield equivalent for that type of land in that year (providing the crop doesn't freeze in the fall). If it is not flooded it should produce an average stubble yield equivalent for that type of land in that year, or be summerfallowed, in anticipation of runoff the following spring.

FEASIBILITY CHECK LIST

	<u>Example</u>	<u>Yours</u>
1. Project acreage with full flood	30 ac	
2. Hydrology: water required to cover the project	60 ac-ft	
Approved water allocation	20 ac-ft	
3. Soils - deep root zone	yes	
- texture	CL	
- moisture holding capacity	2 in/ft	
- suitable for irrigation	yes	
4. Net return per acre (see appendix 1)		
- irrigated acres	\$ 59	
- dry acres	\$ 26	

5. Possible results:

No Flood	Partial Flood	Full Flood	Flooded Out
30 ac x \$26/ac	20 ac x \$59/ac 10 ac x \$26/ac	30 ac x \$59/ac	NOT EXPECTED
\$780	\$1,440	\$1,770	

6. What can you afford to spend on irrigation investment and land levelling? With money at 10% for 10 years, payments would be \$163 per \$1000 borrowed.

A. For the worst outcome - $\frac{780}{0.163} = \$4,785$

B. For the expected outcome over time -

5/10 years - \$1440 = 720
 3/10 years - \$ 780 = 234
 2/10 years - \$1770 = 354

 1,380 $\frac{1,380}{0.163} = \underline{\underline{\$8,024}}$

Beware of the cash flow if the worst outcome occurs early in the project life, can your operation withstand that situation?

APPENDIX 1

	Stubble Crop Dryland		Stubble Crop Irrigated	
	Example	Yours	Example	Yours
Seed	7		7	
Fertilizer - P 05	30 lbs 10		40 lbs 14	
- N	40 lbs 11		60 lbs 17	
Weed Control	15		15	
Crop/Hail Insurance	6		6	
Taxes	3		3	
Fuel	10		10	
Repairs	10		10	
Overhead	7		8	
Operating Interest	8		9	
	87		99	
Crop Yield	25 bu		35 bu	
Price	4.50/bu		4.50/bu	
Gross Return	\$113		\$158	
Net Return	\$ 26		\$ 59	
Extra Machinery Required to Handle Extra Cropped Acres	No		No	
Annual Cost of This Extra Machinery	None		None	
Net Return Including Extra Machinery Costs	\$ 26		\$ 59	

FEASIBILITY OF SUPPLEMENTAL IRRIGATION

Prepared and presented by Tom. W. Hamlin at the Fourth Annual Western Provincial Premier's Conference, Saskatoon, Saskatchewan, November 25 to 27, 1985 /1.

ABSTRACT: Economic viability of supplemental irrigation is site and circumstance specific. The largest contributor to the doubt is the variability of climatic factors. As irrigation extends the time to maturity of most crops, a major consideration has to be the freeze-free period. Sandy soils in areas experiencing only periodic moisture deficiencies and not limited by growth factors other than moisture deficits are the most likely soils to be economically feasible. Producers should only purchase an irrigation system after the fixed costs, operating costs, extra management costs and the resulting cash flow analysis associated with going irrigation have been given a sober appraisal.

Acknowledgement is made for assistance provided by A.G.N. Van Deurzen, Irrigation Economist, Alberta Agriculture and W.J. King, Irrigation Agrologist, Saskatchewan Agriculture.

/1 Tom Hamlin is an irrigation economist with the Irrigation Branch, Saskatchewan Agriculture, P.O. Bag 1000, Outlook, Saskatchewan, Canada, S0L 2N0. Phone (306) 867-9925

FEASIBILITY OF SUPPLEMENTAL IRRIGATION

BACKGROUND

While all irrigation supplements rainfall, the term supplemental is here applied to intensive or full irrigation where most of the water need is provided by rainfall, and a smaller but varying amount of irrigation is required, - some years none. For this paper, the area where supplemental irrigation would occur, in the prairie provinces, has been taken to be synonymous to the black soil zone.

At the close of the nineteenth century private irrigation schemes were evolving as an integral part of farming in dryer areas of western Canada, mainly in the brown soil zone (2).

In the 1880's the Dominion of Canada and the Canadian Pacific Railway were both interested in establishing a chain of settlements from coast to coast. However, they were not prepared to acknowledge the need for irrigation because they feared it would discourage immigration. The drought of the 1890's and farmer lobby for change resulted in a federal survey to determine the land that would be suitable for irrigation (2).

The Northwest Irrigation Act followed. This act established two concepts that have been subsequently retained by provincial legislation since 1930, when control of water and land became a provincial responsibility. The two concepts are:

- (a) publicly administered irrigation districts; and
- (b) water owned by the Crown and its use authorized and controlled by regulation (7).

The first round of district development was by private land promoters. These large private enterprise ventures failed financially though there were substantial speculative gains made in some of the intervening transactions. Then came farmer owned and operated district ventures with minimal government assistance. These too suffered financially. The third phase, and where we are today, was the realization of public involvement as conceptualized in the 1890 legislation. These projects were characterized by gravity supply to each parcel of land. The district projects tended to follow farmer demand but at times promotion took the lead, largely because of the nature of the supply system. Today's technology, as discussed in the next paragraph, allows irrigation to expand by farmer demand and as private investments. The necessary criteria appear to be suitable water and land within two to five miles distance and up to 100 to 300 foot elevation difference. When this combination runs out there is more demand for public projects. (Perhaps a fourth phase of district development is overdue.)

Since 1945 the technological advancement in sprinklers, pumps, etc., has revolutionized irrigation and subsequently increased the number of potential privately funded projects.

This same technology, as verified in yesterday's presentations, has moved the concept of irrigation as a mechanism to support settlement in dryer areas, to the concept of marginal application of water, to ensure uniform growth from plant establishment to harvest.

By the 1960's the frontier of irrigation expansion had moved to the dark brown soil zone. The 1980's has seen this frontier shift to the black soil zone. There were over 12,000 ha (30,000 acres) of irrigated land in Manitoba in 1985; most of it developed since 1980 (4). One out of five irrigation proposals in Saskatchewan, in the last two years, has been from the black soil zone. However, a recent University of Alberta computer simulation study assessed the feasibility of irrigating a well drained - fertile loam to clay loam and found, "Supplemental irrigation in the Edmonton region is not economically feasible for wheat or alfalfa. In the Lacombe area, it is not feasible for wheat and only occasionally for alfalfa hay" (5).

The farmer demand in the black soil zone has not, at this time, warranted or resulted in public projects. In fact, some of the currently installed systems have been at a total investment of less than \$400 per acre, indicating adjacent land and water and minimal equipment and levelling. By comparison a quarter section pivot installed with pumps, etc., costs from \$500 to \$600 per acre.

HOW TO DETERMINE ECONOMIC FEASIBILITY

At one point in our history, we acted as though we thought irrigation was so good, we could impose it on anyone and they would automatically benefit. In the seventy's the emphasis was changing to - Does irrigation pay for me, on this piece of land? An analogy is "Can I with my resources be a successful seed grower?"

It goes without saying, among the prerequisites to irrigation is the assurance of sufficient water and soil/water compatibility.

Economic evaluation of the feasibility of irrigation can be divided into four major elements.

- Existing agriculture.
- Crop production and water requirements.
- Production costs.
- Economic analysis.

Existing Agriculture:

- - - - -

Before irrigation can be contemplated it is essential to have a good perspective of the existing situation. Limiting factors of production should be examined. Limiting factors such as wet, cold spring soil, heat units, growing season risks, evapotranspiration values, moisture deficiency period relative to available supply, can each put absolute limits on the feasibility of irrigation.

The general cropping patterns and rotations of the area, as well as of the particular land are usually available; detailed record adds further advantage to the accuracy of the evaluation.

Production advantages or disadvantages, market prospects for crops, livestock populations and trends of the area can also be taken into account in the final decision.

Water Requirement Crop Production:

- - - - -

Following the examination of limiting factors, the crop response of irrigation has to be determined. Where sophisticated data is available or can be developed, models are available to predict crop response. Sophisticated data referred to includes probabilities of weekly effective precipitation, and probabilities of weekly potential evapotranspiration, the spring soil moisture and temperature, etc. A recently refined method for determining crop response to irrigation is given in the publication "Irrigation Water Requirements in the South Saskatchewan River Basin: An Economic Perspective" (Alberta Agriculture, 1983). Other models are also under review.

Without such data, as is usually the case, in Saskatchewan in particular, the farmer must be confident in the yields projected as a result of applying a certain quantity of water.

Irrigated Crop Production Costs:

All incremental costs and returns have to be determined. The important existing costs subject to increases are seed, fertilizer, herbicides, machinery operation and maintenance, investment and depreciation of any additional farm machinery required, crop insurance, grain storage and labor. In addition to these are the items related to the irrigation investment - cost of capital works, its operation and maintenance and labor. Costs are very site and system specific. Yield increases are primarily site specific.

Economic Analysis:

The economic analysis summarizes the items involved in determining additional costs incurred when converting to irrigation. The producer must closely examine the total annual additional projected revenues resulting from proposed irrigation development, the increased labor, machinery, capital operating fund requirements. Sensitivity analysis should also be conducted, particularly for proposed projects yielding marginal economic returns. How sensitive is the result to yield and price variations?

A PRACTICAL EXAMPLE

A workbook published by the Irrigation Branch, Saskatchewan Agriculture, in 1982, dealt specifically with the partial budget approach to help farmers and their advisors find their own individualized answer to feasibility of irrigation. Other publications of that time period recognized how the idea of irrigation itself was so overwhelming, that it was difficult to look rationally at the question and stressed the need for individual planning.

The partial budget workbook with the aid of Regional Farm Management Specialists developed full budgets on a per acre basis for both rainfed and irrigated production and for both the Swift Current and North Battleford areas.

In the Swift Current area, the comparison was based on a dryland wheat-fallow rotation versus continuous irrigated wheat. North Battleford's budgets were from continuous wheat dryland to continuous wheat irrigated. As a supplement to the partial budget exercise, there was a break even analysis that compared the "cash" and total costs of producing a bushel of wheat using Saskatchewan Crop Insurance yield data as a basis for yields. This exercise indicated, subject to further detailed investigation, that:

1. Irrigation investments for the production of hard wheat can seldom be justified by average management.
2. The total cost of producing a bushel of irrigated or rain fed hard wheat was about the same, \$5.50 to 6.00/bushel.
3. The operating and labor costs only are up to \$1.00 more per irrigated bushel - \$4.00 vs 3.00.

Other obvious observations are:

4. There are fewer production adjustments to make in the more humid situation.
5. Farm machinery complements in the humid areas more closely resemble those required under irrigation.

CONCLUSION

In conclusion the feasibility of supplemental irrigation is site and circumstance specific, dependent upon many independent factors of climate, soils, management, and markets. As irrigation extends the time to maturity of crops, a major consideration has to be the freeze-free period which in turn identifies the need for crop research in this regard. This paper suggests as irrigation has evolved to concentrate on optimizing production there can be advantages in taking up irrigation in subhumid areas as compared to semiarid areas. These advantages lie in the transition from existing agricultural practices, the standard farm machinery component, the farmer production experiences, softer climate, and available markets. The paper also suggests where growing season allows, irrigated sandy soils in subhumid areas can compete very effectively in the production of many standard and most specialized crops of the area, where part of the advantage can be earlier harvest of quality product. A long term advantage lies in continuity of supply (6). On the other hand, the economic feasibility of supplemental irrigation of deep medium to moderately fine textured soils is apt to be very marginal. It is limited in increased production and further limited where the freeze-free period is a problem with rainfed production.

Producers should only purchase an irrigation system after the fixed costs, operating costs, extra management costs, and the resulting cash flow analysis, associated with irrigation investments, have been given a sober appraisal.

TH:bj
85.11.25

J/01/G

REFERENCES

1. A. G. N. Van Deurzen and A. L. Birch, Irrigation Water Requirements in the South Saskatchewan River Basin: Economic Component, 1983, Alberta Agriculture, Economic Services Division, prepared for Alberta Environment.
2. Harvey L. Topham, P. Eng., History of Irrigation In Western Canada, Agriculture Canada, Prairie Farm Rehabilitation Administration (PFRA), 1982. CANCID Project.
3. R. W. Irwin and D. Armitage, Irrigation in Eastern Canada, University of Guelph, Ontario Agricultural College, School of Engineering, for Environment Canada, 1981. CANCID Project.
4. G. C. Jenkins, Water Use in Agriculture in Manitoba, Manitoba Agriculture, Soil and Water Management Section, prepared for Agrologist Institute of Canada, Task Force on Water Use.
5. B. G. McConkey and E. Rapp, Feasibility of Supplemental Irrigation in East Central Alberta, University of Alberta, Agriculture and Forestry Bulletin, Vol. 8, No. 1.
6. Michael Bird, Water To Turn Deficit Into Profit, article from Power Farming, Vol. 64; No. 5, May, 1985.
7. P. H. Pearse, F. Bertrand and J. W. MacLaren, Currents of Change, 1985, Final Report on Inquiry on Federal Water Policy, by Environment Canada, Ottawa.
8. T. W. Hamlin, Can Irrigated Hard Wheat Pay in 1983, Saskatchewan Agriculture, Irrigation Branch, Workbook on Economic Feasibility in Irrigation, Publication 83.02.
9. T. W. Hamlin, Transition to Irrigation, 1983, Saskatchewan Agriculture, Irrigation Branch, Handi-Fact 83.17.
10. T. W. Hamlin and B. H. Ireland, Irrigation Guide, 1984, Saskatchewan Agriculture, Irrigation Branch, Publication 84.00, Prepared as an Update for University of Saskatchewan Publication "Guide to Farm Practice in Saskatchewan, 1984".
11. J. L. Linsley, Irrigation Cash Flows, 1983, Saskatchewan Agriculture, Irrigation Branch, Handi-Fact 83.15.
12. J. L. Linsley, Saskatchewan: Water Use in Agriculture, 1985, Saskatchewan Agriculture, Irrigation Branch, A Report to Agrologist Institute of Canada, October 1985.

IRRIGATION, THE MAJOR PROJECT APPRAISAL*

Prepared by:

Kevin O'Grady**
and
Byron C. Palmer***

- * Paper presented at the Fourth Annual Western Provincial Conference: Rationalization of Water and Soil Research Management: "Irrigation on the Prairies," November 25 to 27, 1985, Saskatoon, Saskatchewan.
- ** Economist, formerly with UMA Engineering Ltd.
- *** Director of Planning and Special Studies, UMA Engineering Ltd., P.O. Box 655, Lethbridge, Alberta.

1.0 INTRODUCTION

When interest in a multi-farm irrigation scheme surfaces, it is accompanied by considerable soul searching by those who expect to be affected. These people can be classified into several roughly homogeneous sets: the owners and operators of the land to be irrigated; those already using water from the same source; technical people who will be responsible for the infrastructure design, construction, installation, training, operation, etc.; government legislators who set policy and authorize the use of resources; and society who, as a group, may be asked to share in some of the costs and can expect to participate in some of the benefits.

In the early days of prairie irrigation, interest in project development often originated with drought-weary farmers. In southern Alberta, there was a period when the CPR and other entrepreneurs developed irrigation projects for various reasons associated with expectations of gaining a financial return, usually by selling irrigated land and/or a water right.

Government Intervention

Financial difficulties in those early years created an awareness that, in general, farmer returns to irrigated agriculture could not bear the entire costs of water diversion, conveyance, storage, delivery, on-farm water control, and specialized equipment. With this awareness

came the realization that others who depend on irrigation, but are a step or two removed from the farm, would be willing to accept some of the direct costs associated with irrigation. This realization put governments into the support of irrigation. Projects whose direct benefits do not cover all project costs may still be economically feasible, when indirect benefits and costs are added to the equation.

Economic Analysis

This concept has been with us for many years, but several difficulties have made economic analysis of irrigation projects troublesome. These have included:

1. How to quantify all the benefits and costs associated with a project including secondary benefits and costs.
2. How to deal with the problem of high early capital costs and later development of agricultural production.
3. How to deal with risk.
4. How to compare the return to investment in irrigation with other investment opportunities.
5. How to analyze multi-objective water use proposals.

Balancing these issues is still more an art than a science and, as such, still requires soul searching by our legislators whose special skills are to exercise the "art of the possible." We technicians are gradually improving analytical tools to deal with these problems.

an acre-ft of water today is preferred to 1,000 acre-ft, 100 years from now. Not until the government recognizes its role in preserving resources and a good life for future generations will this problem be solved."⁽¹⁾ Phillips and Veeman,⁽²⁾ referred to this as "societal goals of intergenerational equity."

Shortening the Development Period

There are agro/engineering strategies for minimizing the problem of high early capital costs and late developing returns. For example, as much land as possible should be developed near the upstream end. Land should be developed in pace with the construction of the distribution works. Sometimes local water supplies can be temporarily developed so that lands can be irrigated from makeshift supplies, while waiting for the distribution system to reach these lands. When the ditch finally reaches the farm, the farmer has already developed some skill in irrigation technology.

One social strategy is to induce experienced irrigation farmers to move into a new project, with the expectation that this will cut down on the learning time that would otherwise be required if all farmers in the area were inexperienced in irrigation.

Risk

Risk has many dimensions in project appraisal. Those that are most frequently recognized include:

Input/Output Analysis

Our economists are refining the techniques of input/output analysis now operationally useful in identifying secondary effects that can be expected under alternative development scenarios. This has been made possible by several factors: those who developed I/O theory; the statistical departments of the provincial and federal governments who have been collecting relevant data for several years; access to computers to crunch the large amount of data required; the necessary software; and finally, an increasing acceptance by economists and decision makers of the validity of the process. Three groups in Saskatchewan are on the cutting edge of I/O technology: the University of Saskatchewan, the PFRA, and the Crown Management Board of Saskatchewan. More will be said about I/O analysis later.

The Discount Rate

The issue of high early capital costs to divert, store, and convey water before any irrigated farm production can begin troubles economists who are accustomed to calculating alternative choices in resource development by bringing future cost and benefit streams to a "net present worth" via a discount rate. A high discount rate penalizes the present value of future benefits. A low discount rate forces decision makers to wonder if the process is realistic. In the case of water resources projects, several authors have given a logical argument for keeping low discount rates for long term project analysis. For example, "at a little over seven percent discount rate,

- . water supply
 - annual
 - seasonal
 - monthly
 - instantaneous
- . climate
 - precipitation amount and timing
 - potential evapotranspiration
 - length of growing season
- . market and production cost fluctuations
- . on-farm husbandry, crop selection, cultural practices, etc.

There is a rapidly expanding literature on agricultural risk identification and management, most of which relies on computer simulation as the analytical base. There are so many variables involved that a major obstacle has been the quantification of the interactions or covariances between the variables. Where many years of crop and weather data have been collected, their covariances can be calculated if two assumptions can be accepted: that the frequency distributions of climate parameters will be about the same in the future as they have been during the period in which data has been gathered, and that weather-yield relationships remain more or less constant. Most people are willing to accept the first assumption, although some are expressing concern about the probable trend toward another ice age, while others worry about the increase in the world's average temperature, resulting from the greenhouse effect of a buildup of carbon dioxide in the earth's atmosphere. The second assumption can be

complicated by plant breeders and new developments in other husbandry techniques. These are ongoing activities that can proceed in an uneven and probably unpredictable pattern.

Finally, there is the problem of choices a farmer must make between high-expected return/high-risk options, and low-return/low-risk strategies.

The technology of risk assessment and minimization in feasibility studies of large irrigation proposals is emerging as a "new kid on the block" and deserves our attention.

Selecting Among Alternatives

Regarding alternative uses of monies for development, conceptually, we can think of whether to invest in irrigation, provincial parks, hospitals, or national defence. This is still very much the sole domain of the politicians; however, the evolving technology of multi-objective water resource planning, which probably had its genesis in the early days of the Tennessee Valley Authority, does provide systematic ways of thinking about alternatives and optimum mixes of alternatives.

In this connection some people criticize the counting of secondary benefits in establishing benefit/costs and net present values of irrigation projects on the basis that almost anything the government invests in will have more-or-less similar secondary benefits.⁽³⁾ We

would welcome enlightenment by data supporting this assertion. We have data showing significant variations in secondary benefits between irrigation projects. It is difficult to imagine that X dollars invested in irrigation in the Diefenbaker Lake area will generate the same secondary benefits as X dollars put into a provincial park in the same region.

Returns to Government

Reference was made previously to various groups who pay for and benefit from irrigation development. There is a perception by some that, when the government invests in irrigation development, a few farmers and local communities get most of the gravy, with very small benefits filtering back to society.⁽³⁾

We completed a study about a year ago which demonstrated that for the 13 irrigation districts of Alberta, their rehabilitation program net benefits accrued in the ratio of 15 percent to the water users and 85 percent to the rest of society, 66 percent in the province and 19 percent to other Canadian provinces. The impact of these investments on the affected parties is a function of a number of issues. For example, if specialty crops are grown and processed in the region, the secondary benefits to the area will be much greater than if only wheat is grown and shipped out for processing elsewhere.

2.0 PROJECT APPRAISAL IN SASKATCHEWAN

The recent Saskatchewan Irrigation Project Appraisal Study,⁽⁴⁾ a joint effort by the Province of Saskatchewan and the federal government, had, as its primary objective, to evaluate the impacts of irrigation development on irrigation farmers, society, and governments. The analysis which focused on seven potential project areas and one grouped regional scheme, all to be supplied from Lake Diefenbaker, used a number of combinations of assumptions or scenarios to produce over 800 benefit cost ratios and their associated net present values. To illustrate the analytical methodology, the remainder of this presentation will focus on the costs and returns to the federal and provincial governments, which can be expected with several alternative assumptions.

The areas identified for the study are displayed in Figure 1. Acreages are approximated in Table 1.

TABLE 1
ACREAGES USED IN THE STUDY

Project	Acres to be Irrigated
Blackstrap	3,900
West Side	59,800
Luck Lake	15,000
Riverhurst East Regional*	87,700
Total	166,400

* The study includes the disaggregation of the Riverhurst East Regional project into four small projects.



Figure 1

3.0 METHODOLOGY

The estimation of the impacts arising from the construction of irrigation works and the subsequent operation of those works and irrigation farming activity was accomplished through several stages. These were:

- a) The economic activity, in terms of the pattern and value of farm expenditures and revenues, that exists at present in each project area in question was estimated using Saskatchewan Agriculture and Statistics Canada information.
- b) The pattern and values of activity when full development would be reached were then estimated. This estimation involved several steps:
 - i) The range of possible development patterns was bracketed by the construction of three possible development scenarios. Each scenario consisted of land use patterns, livestock populations, and agricultural processing activities that could be envisioned, each under increasingly optimistic assumptions.
 - ii) Three irrigated farms were defined such that they could be considered typical of irrigated agriculture under large irrigated block development. Each farm displayed a different enterprise emphasis, i.e., grain, livestock, and specialty crops. The pattern and values of expenditures and revenues for these farms were then estimated.

- iii) The pattern and values estimated in ii) were then aggregated for the three farms such that a different aggregation was determined for each scenario as a different combination of typical farms would exist for each scenario.
- c) The direct economic impact associated with the development of irrigated agriculture for each scenario was then estimated as the difference between "what is" (step a) and "what will be" (step b).
- d) The secondary economic impacts associated with the development of irrigated agriculture were estimated by the use of a static input/output (I/O model). The next section describes the particular I/O model used. The direct impacts estimated in c), along with direct construction and operation and maintenance expenditures, were input to the I/O model to determine the secondary impacts.
- e) Though a static I/O model will estimate economic impacts, the model does not offer any insight as to the timing of impacts. Such impacts can be expected to appear as the project develops to maturity. As such, construction phasing and the farmer uptake paths were assumed to take the forms shown in Table 2. These figures indicate the proportion of total impacts allocated to each year.
- f) The direct and indirect impact streams which could be considered as revenues or costs to government were isolated.
- g) The impact streams were discounted at the three, five, and ten percent discount rates.

TABLE 2: ASSUMED PERCENT OF TOTAL CONSTRUCTION AND UPTAKE BY YEAR AND PROJECT

Year	West Side		Luck Lake		Blackstrap		Riverhurst East Regional	
	Construction	Uptake	Construction	Uptake	Construction	Uptake	Construction	Uptake
1	14.0	7.0	5.0		5.0		4.6	
2	15.0	7.0	50.0		70.0		11.4	
3	8.0	7.0	35.0	10.0	20.0	15.0	16.9	
4	6.0	7.0	5.0	10.0	5.0	15.0	22.8	7.0
5	6.0	7.0	3.0	10.0		15.0	15.7	7.0
6	5.0	7.0	2.0	10.0		15.0	15.0	7.0
7	5.0	7.0		10.0		3.6	13.6	7.0
8	8.0	7.0		5.0		3.6		7.0
9	8.0	7.0		5.0		3.6		7.0
10	7.0	7.0		5.0		3.6		7.0
11	5.0	6.0		5.0		3.6		7.0
12	4.0	6.0		5.0		3.6		7.0
13	3.0	6.0		5.0		3.6		7.0
14	3.0	6.0		5.0		3.6		6.0
15	3.0	6.0		5.0		3.6		6.0
16				5.0		3.6		6.0
17				5.0		3.6		6.0
18								6.0

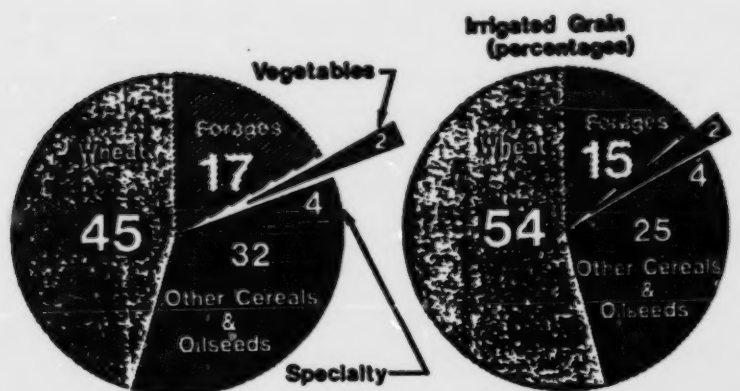
Development Scenarios

The three development scenarios were defined largely as a result of an information workshop sponsored by the Saskatchewan Water Corporation (see Figure 2).*

The grain scenario was developed as representative of the irrigation activities within a grain oriented economy as is evolving in Saskatchewan today. Crop mixes are based on current crop patterns in the South Saskatchewan River Irrigation District (SSRID) and observations from the workshop. The main difference between the scenario and the SSRID is that the wheat grown under the grain scenario is largely soft wheat.** The livestock scenario was designed to demonstrate a movement away from the predominant Saskatchewan grain culture and is more comparable to the beef component of the larger irrigation districts in Alberta (the Eastern, Bow River, St. Mary River, and Lethbridge Northern Irrigation Districts). Only beef cows and feeders were considered in this scenario, as production of dairy and poultry products are administered federally on the basis of provincial population and production precedents.

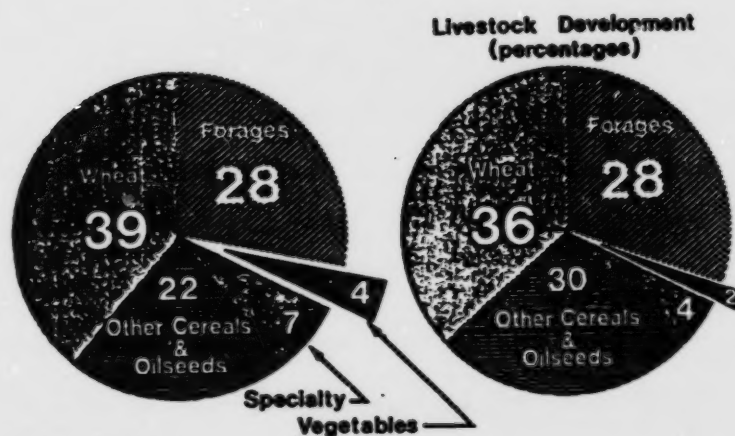
* Ideas as to possible development profiles were offered by farmers, provincial and federal employees, and consultants. The workshop was held on March 7, 1985 in Regina.

** The percentage of irrigated land in soft wheat production in the SSRID #1 is increasing with the introduction of ready markets for the product. The acreage in soft wheat and HY320 is expected to total one-third or more of the irrigated acres in 1985, with a subsequent decline of hard wheat.



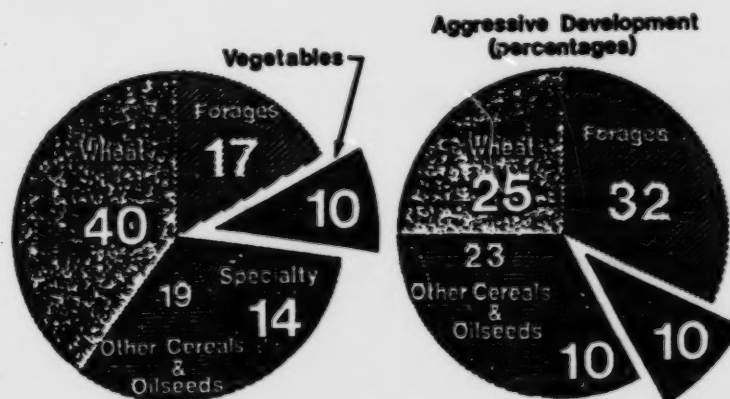
Current Crop Mix
SSRID #1 District

Grain Scenario



Average of:
SMRID, ED, LNID, BRID

Livestock Scenario



Taber ID

Aggressive Scenario

FIG. 2

The aggressive scenario was developed as the most optimistic of the three. It combines the heavy vegetable and specialty crop emphasis, as is visible in the Taber, Alberta Irrigation District, with the livestock emphasis of the livestock scenario (Table 3). It is expected that long-term concentrated and coordinated effort on the part of both the public and private sectors would be required to bring about this scenario.

The I/O Model

The study utilized both the Saskatchewan Input-output Transactions Resource Use Model (SITRUM), which is owned and operated by the Crown Management Board of Saskatchewan and the Prairie Income and Expenditures Model (PIE), which is owned and operated by the Prairie Farm Rehabilitation Administration. Both models are static linear input-output models describing the Saskatchewan economy based on 1979 data. The SITRUM model was utilized to estimate government revenues and expenditures. This model segments the economy into 85 sectors purchasing any of up to 116 commodities.

Sources of Government Revenues and Costs

The sources of direct plus indirect government revenues and costs arising from the increased economic activity were identified as:

TABLE 3
SCENARIO CHARACTERISTICS: CROP ACREAGE,
LIVESTOCK AND AGRICULTURAL PROCESSING
PER 10,000 ACRE IRRIGATED BLOCK

Enterprise	Grain	Livestock	Aggressive
Forages and Pasture	1,400	2,700	3,200
Soft Wheat	2,900	2,600	2,400
Hard Wheat	2,400	1,000	0
Other Cereals	900	2,400	1,500
Oilseeds	1,400	500	800
Specialty	400	400	1,000
Vegetable	200	200	1,000
Summerfallow	400	200	100
Total Acres	10,000	10,000	10,000
Beef Cows	200	1,500	1,500
Feeders	500	6,500	6,500
Percent of Irrigated Acreage Processed in the Province			
Wheat	1	1	2
Forages	5	10	15
Cereals	1	1	2
Oilseeds	30	30	50
Specialty and Vegetable	75	75	90

Note: The land use patterns described in Table 3 and Figure 2 may appear to differ. The pie charts of Figure 2 do not include summerfallow in the percentages.

Revenues - direct personal tax

- indirect tax
- corporate tax
- royalties

Costs - structural subsidy

- construction
- operation and maintenance
- aid to farmers

Given expenditure by the government on the latter three costs, there will be an increase in revenues to the government and in structural subsidy costs to the government. Transfers, such as social welfare and unemployment insurance were not included in the analysis, as it would not be obvious without a great deal of demographic data, whether a change in such transfers would be a benefit or a cost to government.

Direct Personal Tax Revenue

Due to government spending there can be expected an increase in the income of input suppliers, not the least of which is labour. This revenue was estimated by SITRUM, however, the estimate did not discern a difference between the provincial and federal governments. Over the years 1979 to 1983, the average proportion of direct taxes collected in Saskatchewan by the provincial and federal governments was, respectively, .356:.644.⁽⁵⁾ This proportion was used to allocate the direct tax revenue to each government.

Indirect Tax Revenue

Indirect taxes, as defined by SITRUM, included such items as federal excise tax, import duties, provincial sales tax, motor vehicle licenses, property tax, capital tax, and place of business tax. As with direct tax revenue, SITRUM provided a total estimate of indirect taxes paid to all levels of government. Over the years 1979 to 1983, the average proportion of indirect taxes collected in Saskatchewan by the provincial, federal and municipal governments was .386:.324:.290.⁽⁶⁾ Indirect tax revenues were allocated by this proportion. Municipal taxes were ignored for this analysis, thus estimated expenditure ratios will not reflect municipal revenues or costs.

Corporate Tax Revenue

By SITRUM definition, this tax paid to provincial and federal governments includes corporate income taxes and taxes paid by government business enterprise. These taxes were not reported directly by SITRUM but were included in the SITRUM category of "Other Operating Surplus." The SITRUM base run reported Other Operating Surplus as \$2,953 million in 1979. Corporate taxes collected in 1979 by the provincial and federal governments were \$101 million and \$223 million, respectively.⁽⁷⁾ Thus, the corporate tax collected by the provincial and federal governments, respectively, was estimated as 3.4 percent and 7.55 percent of Other Operating Surplus.

Royalty Revenue

As the shock of increased economic activity ripples through the economy, royalty revenue may be expected to increase. Royalties, typically arising from mining activity, accrue to both provincial and federal governments. SITRUM reported provincial royalty revenues directly; however, federal royalties were included in the category of Imports to Saskatchewan. Imports in 1979, as reported by the base run of SITRUM, were \$6,639 million. In 1979, \$1 million in royalties were collected in Saskatchewan by the federal government.⁽⁸⁾ Thus federal royalties were estimated as 0.0151 percent of Imports.

Structural Subsidies

Structural subsidies paid by the provincial and federal governments together were estimated by SITRUM. The term "structural" refers to those subsidies which existed in the economy as it was structured in the SITRUM base year of 1979. This is to distinguish these subsidies from any additional government contributions to the cost of production which may be initiated to promote the development of irrigation agriculture in Saskatchewan. Structural subsidies include all government expenditures to all sectors of the economy to reduce, from the producers' point of view, production costs. Agriculture is only one of many sectors to which these subsidies are paid.

As with direct and indirect taxes, SITRUM did not discern the subsidy paid by each government. Over the years 1979 to 1983, the average

proportion of structural subsidies paid to Saskatchewan by the provincial and federal governments was .36:.64, respectively.⁽⁹⁾ Structural subsidies were allocated by this proportion.

Aid to Farmers

Two distinct government programs to aid farmers in adopting irrigation technology were included in this analysis. Federal aid was represented by a PFRA grant of \$2,200 per farm to be used for on-farm development of irrigation works.

Provincial aid was provided in the form of a grant identical to the Family Farm Improvement Branch grant which was part of Saskatchewan Agriculture policy from April 1984 to March 1985. For the purposes of development of on-farm irrigation works, a grant of \$100 per irrigated acre was offered to a maximum of \$50,000 per single unit farm. The grant would be paid over three years with a maximum of 60 percent paid in the first year; 20 percent would be paid in each of the second and third years. It was assumed that these grants would be paid in accordance with the uptake schedules in Table 2.

Construction, Operation and Maintenance Costs

Information as to the cost of construction, operation and maintenance of the main and secondary works was provided by SWC and PFRA. Fiscal revenue-cost ratios were calculated under different assumptions as to cost sharing.

Description of Economic Activity

For the purposes of analysis, the economic activity assessed by the study was divided into four major subactivities. These were:

- a) construction of irrigation main and secondary works,
- b) operation and maintenance of irrigation works,
- c) on-farm investment in irrigation works and subsequent replacement,
and
- d) farm operations.

These groups are distinct from each other in expenditure patterns, hence, also different in impact on the economy. The groups are also distinct in terms of the time horizon over which costs are incurred and benefits experienced. All revenue and expenditure streams were discounted at the three, five, and ten percent levels.

Construction of Main and Secondary Works

The direct plus indirect impacts of government expenditure on the construction of the main and secondary works were reported by SITRUM. Construction of the main and secondary works was assumed to start in year one, and to proceed at the rates described in Table 1. Thus, if 25 percent of construction was to have occurred in a given year, then 25 percent of the fiscal revenues and expenditures related to construction, as reported by SITRUM, were assumed to occur in that year.

Operation and Maintenance

The economic impacts of government expenditures on operation and maintenance of the main and secondary works were reported by SITRUM as the annual impact occurring when the entire system is in full use. In early years, prior to the completion of construction, it could be expected that this expenditure would be less than that reported by SITRUM. However, it was assumed that the annual expenditure reported by SITRUM was applicable in all years, from the start of uptake to year 50, the early years requiring heavy capital expenditure on land, buildings, and equipment.

On-Farm Investment and Replacement

The development of an irrigated farm from a dryland base requires a significant expenditure on the part of the farmer. Irrigation equipment must be purchased and installed, and a change in machinery and, possibly, storage facilities will be required. Initial investment and replacement purchases were estimated for each year from the start of uptake to year 50. Investment was assumed to follow the uptake patterns set out in Table 1. Replacement was assumed to have started in the eighth year after investment began.

Results of the economic impact, as estimated by SITRUM, included only the impacts of initial farm investment. Replacement expenditures were estimated as a proportion of initial investment and added to that investment. This proportion was multiplied by the SITRUM output to obtain the impacts of both activities.

Farm Operation

The impact of farm operations on the provincial and federal governments was based on the three farm types defined by the CSIPA study. Farm input expenditures, production, and income were projected for 15 years utilizing the PC Top Management Budgeting Program operated by Dr. Richard Schoney and Farmlab at the University of Saskatchewan. Based on these projections, SITRUM reported the annual impact on the economy for farming operations. At the start of the 50-year period, where uptake was not yet complete, the annual farming impact followed the uptake rates described in Table 2. Thus, in a year where 25 percent of the uptake was accomplished, 25 percent of the annual impact was assumed to occur. Full annual impacts occur when uptake is complete.

4.0 RESULTS OF ANALYSIS

Although government revenues and expenditures were estimated for all four regions, the revenue-expenditure ratios are reported only for the total project area of 166,000 acres. Table 4 displays these ratios with no distinction made as to which government pays the costs. Table 5 presents the revenues, expenditures, and ratios under the assumption that the provincial and federal governments share equally the construction costs. In Table 5, it has also been assumed that the bulk of the operation and maintenance costs are paid by farmers. The provincial government is assumed to pay for 50 percent of these costs in year one, 40 percent in year two, and so on until year six where farmers pay 100 percent of the operation and maintenance.

TABLE 4: DIRECT PLUS INDIRECT REVENUES
AND EXPENDITURES ACCRUING TO THE PROVINCIAL AND
FEDERAL GOVERNMENTS FROM ALL ACTIVITY, BY SCENARIO*

(millions of 1985 dollars)

Present Value	Grain	Livestock	Aggressive
Provincial Revenues			
3% Discount	117.3	130.0	151.1
5% Discount	79.6	87.6	101.1
10% Discount	39.0	42.2	47.8
Federal Revenues			
3% Discount	153.2	171.6	199.8
5% Discount	103.9	115.5	133.5
10% Discount	50.8	55.4	62.9
Government Expenditures			
3% Discount	377.1	379.2	381.3
5% Discount	316.0	317.5	318.8
10% Discount	230.6	231.3	232.0
Revenue/Expenditure			
3% Discount	0.72	0.80	0.92
5% Discount	0.58	0.64	0.74
10% Discount	0.39	0.42	0.48

* Total for all projects, West Side, Luck Lake, Blackstrap, and Riverhurst East Regional.

TABLE 5: DIRECT PLUS INDIRECT RETURNS TO
GOVERNMENT WITH 50/50 SHARE OF CONSTRUCTION COSTS*

(millions of 1985 dollars)

Present Value	Grain	Livestock	Aggressive
<u>Provincial Government</u>			
3% Discount			
Revenues (M\$)	117.3	130.0	151.1
Costs (M\$)	137.7	139.0	139.9
Revenues/Costs	0.85	0.94	1.08
5% Discount			
Revenues (M\$)	79.6	87.6	101.1
Costs (M\$)	124.9	125.9	126.5
Revenues/Costs	0.64	0.70	0.80
10% Discount			
Revenues (M\$)	39.0	42.2	47.8
Costs (M\$)	101.3	101.8	102.1
Revenues/Costs	0.39	0.41	0.47
<u>Federal Government</u>			
3% Discount			
Revenues (M\$)	153.2	171.6	199.7
Costs (M\$)	123.7	124.5	125.7
Revenues/Costs	1.24	1.38	1.59
5% Discount			
Revenues (M\$)	103.9	115.5	133.5
Costs (M\$)	112.5	113.0	113.7
Revenues/Costs	0.92	1.02	1.17
10% Discount			
Revenues (M\$)	50.8	55.4	62.9
Costs (M\$)	91.7	91.9	92.2
Revenues/Costs	0.55	0.60	0.68

* Province pays 50 percent of operation and maintenance in year one, 40 percent in year two ..., and 10 percent in year five, remainder is paid by farmer.

5.0 CONCLUSION

Although governments often invest in a project such as irrigation on behalf of society or the economic community, governments themselves realize a real return directly to government accounts. In the case of the proposed irrigation project, total government returns are in the range of \$90 million to \$350 million, depending on the discount rate, construction phasing, uptake rate and scenario, and demonstrate that much or all of the government's contribution can be expected to be recovered directly to the government. Overall benefits to society will of course be much higher.

6.0 REFERENCES

- (1) Beard, L.R., "Computer Impacts on Water Resources Engineering," Proceedings of the Specialty Conference, Buffalo, N.Y., June 10 - 12, 1985, sponsored by the American Society of Civil Engineers.
- (2) Phillips, W.E. and Veeman, T.S., "Alternative Incentives for Water and Soil Conservation," presented at the annual conference of the Canadian Water Resources Association, Edmonton, October 23 - 25, 1985.
- (3) Pearse, P.H., F. Bertrand, and J.W. MacLaren, "Currents of Change, Final Report, Inquiry on Federal Water Policy," Ottawa, September 1985, p. 105.
- (4) Saskatchewan Water Corporation and the Prairie Farm Rehabilitation Administration, "Saskatchewan Irrigation Project Appraisal Study," October 1985.
- (5) Statistics Canada. Provincial Economic Accounts, 1968 - 83, catalogue 13-213, Ottawa, 1985.
- (6) Ibid.
- (7) Ibid.
- (8) Ibid.
- (9) Ibid.

FOURTH ANNUAL
WESTERN PROVINCIAL CONFERENCE
RATIONALIZATION OF WATER AND SOIL RESEARCH AND MANAGEMENT
"IRRIGATION ON THE PRAIRIES"

IRRIGATION, THE INDIVIDUAL PROJECT APPRAISAL
By: Gerry Gross and Les Bohrsen, Irrigation Agrologists
with the Irrigation Branch of Saskatchewan Agriculture

-ABSTRACT-

This paper deals with the factors considered when performing a feasibility study for an individual irrigation project. Factors identified are the physical factors of water, soils and engineering options along with identifying an individual's reasons for wanting to develop irrigation. This paper then proceeds to describe how to recognize an individual's potential for irrigation development based on equity in the farm operation along with operator knowledge and managerial ability.

The paper concludes by saying that irrigation is not for everyone and that it is our responsibility as professionals to identify and assist those individuals who have the potential to be successful in irrigation farming.

LT002/H

The topic which I have been asked to speak on today is Irrigation, The Individual Project Appraisal. We at the Irrigation Branch of the Saskatchewan Department of Agriculture are responsible for the Administration and Coordination of Saskatchewan's Irrigation Assistance Program. We do not take this responsibility lightly as we feel that sound administration of the program is essential to ensuring the program's success, however, an area which we are responsible for and of which we feel is even more important than providing sound administration for the program is the area of economic counselling or feasibility studies for people who wish to develop irrigation.

If we simply provide an efficient mechanism through which an individual can develop irrigation without trying to ensure the applicant's future viability then we have done no service to anyone.

How do we go about performing a feasibility study? The procedure is as follows; in order to determine the feasibility of a potential individual irrigation project we have to address three main areas; first, the physical factors affecting irrigation development, second, the client's reasons for wanting development and third, the economic realities of irrigation development.

To assist us in determining the feasibility of a project, we require the help of two key players in irrigation development in Saskatchewan, namely the S.W.C. and P.F.R.A..

The S.W.C. is responsible for determining the amount of water available for allocation to any potential project in Saskatchewan and ultimately is responsible for providing a water supply agreement between the province and the applicant should a project be authorized and constructed. The S.W.C. also provides engineering services for the development of irrigation projects in Saskatchewan.

The P.F.R.A. are major players in the provincial irrigation program by providing engineering services for the development of irrigation projects in Saskatchewan. P.F.R.A. have special expertise in the construction of dams and have extensive knowledge in the operation and design of backflood irrigation schemes.

With the help of people from these two agencies, we will start the process by having a look at the physical factors.

A) THE PHYSICAL FACTORS

The Saskatchewan Department of Agriculture, the S.W.C. and the P.F.R.A. perform duties as I have outlined earlier to provide information on the following physical factors:

1) WATER: SOURCE AND AVAILABILITY

The S.W.C. provides preliminary hydrology information on the source and availability. Is the water available all summer and if so how much or is it only available during spring flood?

2) SOIL-WATER COMPATABILITY

The soils section of the Irrigation Branch determines if soil and the water compatibility exists.

3) SOIL-IRRIGATION EQUIPMENT COMPATABILITY

If sprinklers are to be used the equipment must be designed with soil characteristics in mind. The soils section of the Irrigation Branch provides recommendations in this area.

4) IRRIGATION DEVELOPMENT OPTIONS

What development options are real options for the project. Extension Services of Saskatchewan Agriculture, the S.W.C. and the P.F.R.A. can provide an opinion as to which options have potential from an engineering perspective.

B). REASONS FOR WANTING IRRIGATION DEVELOPMENT

We have identified five reasons people have for wanting irrigation development:

#1. TO SECURE WATER RIGHTS

In the areas where only limited water is available for allocation, so as to add to the value of the land for either resale value or future generation on a family farm.

#2. STATUS OR ENJOYMENT

Some people feel that owning a pivot is a good status symbol, while others who really enjoy farming want a irrigation system simply because it is fun producing big yields.

In these two examples # 1 & 2, the question is not so much is it feasible, but rather is it possible and how much will it cost. In these cases our services are required to facilitate the development of irrigation project and the physical factors are the most important.

#3. IRRIGATION DEVELOPMENT TO SAVE THE FARM

Some clients feel that irrigation might be their last hope to turn around a financially troubled farm.

#4. IRRIGATION DEVELOPMENT TO INCREASE PRODUCTION

Of a specific product for a real market. An example would be forage production for a livestock operation.

#5. IRRIGATION DEVELOPMENT FOR SPECULATIVE PURPOSES

An example of this would be an individual who wants to invest in either more land or irrigation development and is very interested in what will happen to his cash flow position while waiting for the economy to turn around.

In examples 3, 4 & 5, once the physical factors have been determined, then the economic feasibility becomes very important. This brings us to the third main area for discussion - the economic realities.

C). ECONOMIC REALITIES OF IRRIGATION DEVELOPMENT

The first step in determining the economic realities is to determine where the client is starting from by assessing his present operation.

Observe the operation and ask questions where necessary to determine the following:

1.) Livestock - is livestock a part of the farm? How will the livestock enterprise tie in with the irrigation? Will the livestock operation be expanded along with the irrigation?

2.) The Present Cropping Scheme - What is the present cropping scheme and present yields?

3.) Intended Cropping Scheme - What is the intended cropping plans on the newly irrigated lands and what yields are expected?

4.) The Operators Knowledge - what is the operators knowledge of herbicides and fertilizer use?

5.) Machinery Adequacy - Is the present complement of machinery adequate to allow for irrigation expansion or will extra investment be required.

6.) Facility Adequacy - will extra investment in facilities be required to complement the intended irrigation development. Extra facilities might be for the storage or drying of grain or for handling a larger number of livestock.

Once we have answers to these questions we are in a better position to judge the client's financial strength and managerial ability. These observation and judgement allows us to place the client and his operation into one of the number of different categories based on equity levels and managerial ability.

In doing so it allows us to concentrate on a type of counselling program which will suit the client's needs.

For this discussion I will concentrate on the following four categories:

TYPES OF OPERATIONS AND OPERATORS

- #1. Low equity - Average management
- #2. Low equity - Good management
- #3. High equity - Average management or
- #4. High equity - Good management

For the purpose of this discussion, I am assuming that both groups of people, those with high and low equity, will borrow money for the irrigation system, but only those with low equity will require extra investment, over and above the irrigation development, to purchase required facilities and equipment. The amount of extra capital purchases required is an important indicator of the individual's present position and helps us considerably as we tend to error on the low side of management, if equity is low, and the high side of management when equity is high.

Also, for the purpose of this discussion, I am going to make the following assumptions supported by the attached appendixes and I will base my remarks on a 1/4 section pivot installation and on alfalfa production.

ASSUMPTIONS

#1). Irrigation development costs are as outlined in Appendix 'A'. Pivot system cost is \$514.00 /acre.

#2). Haying equipment required for a 1/4 section of alfalfa production is as outlined in Appendix 'B'. Average cost based on a combination of used and new equipment is \$211.00 /acre

#3). Annual investment costs based on 25% cash and 75% financed are as outlined in Appendix 'C'. The irrigation system annual investment cost is \$71.00 while the haying equipment, if required, costs \$45.00 per year.

#4). Production cash costs and yields are as outlined in Appendix 'D' with total annual cash costs being \$150.00 /acre with average management producing yields of 3.5 tons and \$165.00 /acre with good management producing yields of 4.5 tons. Alfalfa hay is valued at \$75.00 /ton.

As I have said for discussion I will illustrate those people in the low equity group as being those who will require investment in equipment in addition to the pivot, while those in the high equity will not.

Example #1 Low equity - Average management
 Low equity - Good management

	<u>Average Mgmt</u>	<u>Good Mgmt</u>
Yield/acre	3.5	4.5
Gross Income	\$262.50	\$337.50
Cash costs	150.00	165.00
Annual Invest. Costs		
- Irrigation equip.	71.00	71.00
- Haying equip.	<u>45.00</u>	<u>45.00</u>
Net Income	- \$ 3.50	+ \$ 56.50

-The key is determining the operators managerial potential.

Example #2 High equity - Average management

High equity - Good management

	<u>Average Mgmt</u>	<u>Good Mgmt</u>
Yield/acre	3.5	4.5
Gross Income	\$262.50	\$337.50
Cash costs	150.00	165.00
Annual Invest. Costs		
- Irrigation equip.	71.00	71.00
- Haying equip.	<u>-</u>	<u>-</u>

Net Income + \$ 41.50 + \$101.50

*NOTE: The calculations used in both examples does not include the opportunity cost on the money required to obtain the financing

In conclusion, we would like to say that irrigation farming is no different from any other type of highly capitalized intensive farm enterprise, as equity drops management levels must improve. The example we have used in this paper to illustrate our concerns regarding extra investment could have just as easily been a grain operation, where the extra investment required would be machinery with more capacity along with grain facilities.

The message which we have tried to convey is that irrigation development is not for everyone and we as professionals when performing an on farm project appraisal should identify those people for which irrigation is well suited and, those people for which irrigation would cause serious financial difficulties. Our advice should follow accordingly.

LT002/D

APPENDIX 'A'

IRRIGATION INVESTMENT COSTS

A. Irrigation Development CostsEXAMPLES

#1. 40 acres sideroll (new)	Cost
one lateral 5" 1/4 mile	\$8500
pto pump and fittings	2800
6" mainline @4.00/ft x 1600'	6400
	<u>\$17700</u>

$$\frac{17700}{40} = \$442.50/\text{acre}$$

#2. 133 acre pivot (new)	
7 tower electric pivot -	
high pressure ,800 gal/min	\$40000
75 hp pump @ 150/hp	
fitting & gauages	11250
mainline - 1800' 8" @4.35	7830
safety wire & generator at	
pivot point	9300
	<u>\$68380</u>

$$\frac{68380}{133} = \$514.00/\text{acre}$$

Other Considerations:

1. Size of intended development -

On small acreages sideroll, big gun, handmove systems or flood irrigation may be the most feasible to consider. As acreages increase the pivot or linear move system become more cost competitive to install.

2. Site preparation -

The cost of developing the pumpsite varies considerably with the water source and must be considered in the development cost.

3. Land preparation -

The cost of the removal of trees and/or the filling of sloughs and/or general levelling required to enable the intended system to both operate and provide uniform application must be considered in the development cost.

APPENDIX 'B'

FORAGE ENTERPRISE EQUIPMENT

130 acres - assume tractor is available on the farm

	<u>NEW PRICE</u>	<u>USED PRICE</u>
New Square Baler	\$12,000.00	\$ 7,500.00
New 12' Haybine	10,000.00	7,500.00
New 56 bale - balewagon	<u>13,000.00</u>	<u>5,000.00</u>
TOTAL COST	\$35,000.00	\$20,000.00

Average equipment investment cost based on a combination of new and used equipment:

$$\frac{35,000.00 + 20,000.00}{2} = \$27,500.$$

Average equipment investment cost per acre

$$\frac{\$27,500.00}{130 \text{ ac.}} = \$211.00$$

A heavy disc will also be required but probably could be rented when required for this size of project.

APPENDIX 'C'

INVESTMENT COST SUMMARY

1. Irrigation System (cost per acre)

Pivot - financed at 13% over 10 years (.1843)
- 25% cash payment - 75% financed

<u>TOTAL COST</u>	<u>CASH REG'T</u>	<u>AMOUNT FINANCED</u>	<u>ANNUAL INVEST. COSTS</u>
\$514	\$128.50	\$385.50	\$71.00

2. Haying equipment (cost per acre)

- financed at 13% over 5 years (.2843)

<u>TOTAL COST</u>	<u>CASH REG'T</u>	<u>AMOUNT FINANCED</u>	<u>ANNUAL INVEST. COSTS</u>
\$211	\$ 52.75	\$158.25	\$45.00

APPENDIX 'D'
ALFALFA PRODUCTION BUDGET

<u>Budget</u>	GOOD MGMT <u>\$/Acre</u>	AVERAGE MGMT <u>\$/Acre</u>
Seed (\$20 over 5 yrs)	4	4
Fertilizer N P	17	12
Herbicides		
Pesticides		
Twine	5	5
Water Tax (for those on group projects)		
Pumping fuel	45	30
Irrigation Maintenance (1% of capital cost)	6	6
Equipment: Fuel	14	14
Repair	14	14
Hired Labor	15	15
Breaking (\$25 over 5 yrs)	5	5
Land Taxes	4	4
Other (Marketing)	10	15
Overhead	10	10
Operat. Interest (14% for 9 months)	<u>16</u>	<u>16</u>
TOTAL CASH COST	165	150
RANGE OF YIELDS:	GOOD	AVERAGE
T/ac	4.5	3.5

T002/G

THE ECONOMIC AND FINANCIAL FEASIBILITY OF IRRIGATION

BY
RONALD DESJARDINS
AND
JULIE EGGLESTONE

PRODUCTION AND RESOURCE
ECONOMICS BRANCH

ALBERTA AGRICULTURE

INTRODUCTION

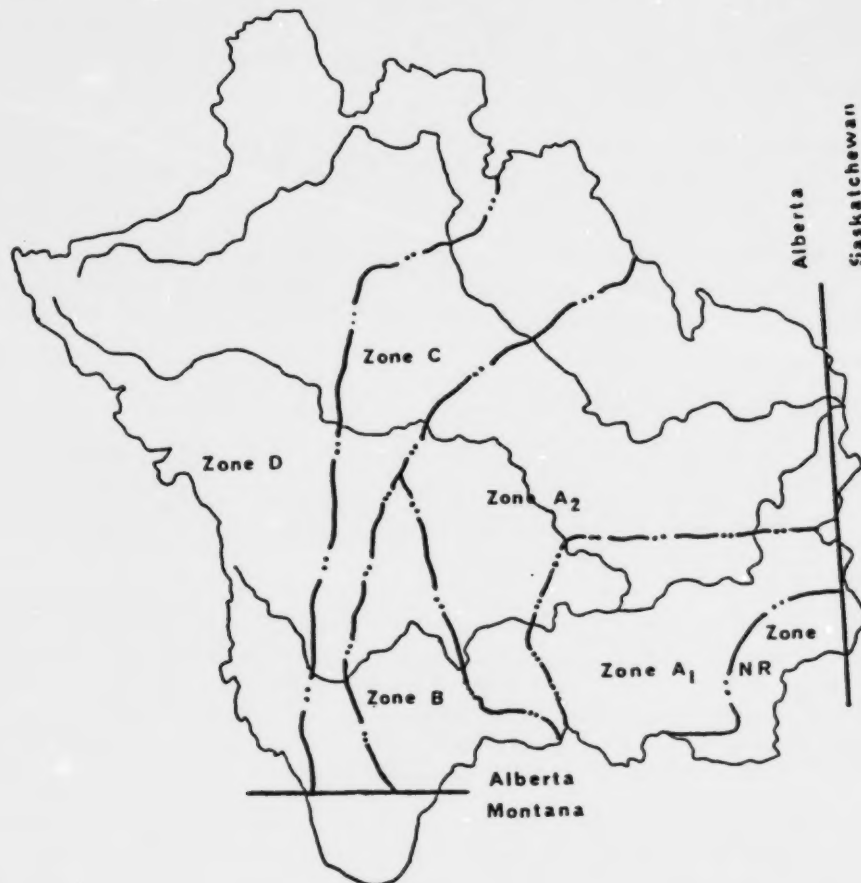
1.1 Background

The production costs of many agricultural practises have been increasing steadily over the past few years. This study is involved with the changing costs of irrigation during the period 1982-1984 and their implications on the feasibility of irrigation intensification/extension and expansion. Inflation in the agricultural industry has caused costs to increase at a greater rate than revenues, thereby causing a price/cost squeeze. Because of the importance of irrigation in increasing agricultural productivity and output, it was imperative to undertake such a study as this to determine the future potential of irrigation extension/intensification and expansion. The main purpose of this study is, therefore, to assess the future economic and financial feasibility of existing and/or undeveloped irrigated areas.

The reader is cautioned that the results of both the economic and financial analyses relate to a set of specific assumptions and are not applicable globally. The conclusions drawn on the feasibility of adoption of irrigation are based on a given farm size, crop mix, input combination, yields, input costs and output prices. Sensitivity analysis was done to examine the outcome under different price regimes, yield variations and changes in other variables. These should be used in conjunction with the results from the main analyses. The analysis takes into account all costs and benefits of irrigation expansion and intensification. It must be noted that with irrigation expansion and intensification, considerable government expenditure in infrastructure will be needed.

Finally, other factors that might restrict adoption of irrigation have not been taken into account. These include market restrictions (e.g. quota); alternate use of capital (on-farm and personal); availability of credit; government or other restrictions; environmental concerns and other externalities (including aversion to risk and other farmer related characteristics). The financial analysis includes a cost of credit but assumes that it will be available.

SOUTH SASKATCHEWAN RIVER BASIN - AGROCLIMATIC ZONES



Zone	Characteristics	Zone	Characteristics
A1	> 1650 Heat Units (5°C) > 140 Day Growing Season (-2°C) 250-300 mm Moisture Deficit	C	1150-1350 Heat Units (5°C) 120-140 Day Growing Season 150-250 mm Moisture Deficit
A2	1350-1650 Heat Units (5°C) 120-140 Day Growing Season (-2°C) 250-300 mm Moisture Deficit	D	< 1200 Heat Units (5°C) < 120 Day Growing Season < 150 mm Moisture Deficit
B	1350-1650 Heat Units (5°C) 120-140 Day Growing Season (-2°C) 200-250 mm Moisture Deficit	NR	Not Rated

Source: Van Deurzen, A.G.J. and A.L. Birch (1983), Irrigation Water Requirements in the South Saskatchewan River Basin: Economic Component, Economic Services Division, Alberta Agriculture.

1.2 Objectives

- (i) To determine the economic feasibility of irrigation intensification and expansion in irrigation climatic zones A1, A2, B, C and D (see Figure 1).
- (ii) To evaluate the financial feasibility of the intensification and expansion of irrigation in the five irrigation climatic zones of southern Alberta.
- (iii) To estimate the impact of the change in cost of production and in revenue which occurred between 1982 and 1984 on the economic and financial feasibility of irrigation intensification and expansion.

2.0 Methodology and Assumptions

- (i) Marginal analysis was employed in this study. Performance criteria used were benefit-cost ratio (B/C), net present value (NPV) and annual equivalent cash flow (AECF). The analysis was based on a 10,000 acre block of land with average crop mix by irrigation climatic zone.
- (ii) Economic and financial analyses were employed, the economic results are presented from the total economy's point of view and the financial results from the individual farmer's point of view. Residual land values were included in the financial but not in the economic base cases. The converse was tested through sensitivity analysis. No shadow pricing was undertaken.
- (iii) A real discount rate of 5% was used. This was based on a constant relationship between costs and product prices (inflation was assumed to be zero), a nominal interest rate of 12 to 14% and an inflation rate of 7 to 9%.
- (iv) Transfer payments, including taxes and subsidies, crop insurance, Western Grain Stabilization payments, interest on operating and investment capital, and annual incremental operating capital were evaluated in converting from economic to financial analysis.
- (v) Net returns reported were returns to land, labour, management and on-farm existing investment.
- (vi) For financial analysis, zero equity and an interest rate of 13% was assumed for all new investments. All grants and subsidies, for which farmers undertaking the various alternatives are eligible, were evaluated. Crop insurance claims were assumed to be twice the value of crop insurance payments, based on federal government subsidization of the program. Western Grain Stabilization benefits and payments were assumed to be equal. Annual incremental operating capital was valued at 85% of the change in costs for the next year. Salvage value of new equipment was based on the undepreciated value at the end of the project.

Where appropriate, residual land values were assumed to be equal to the total improvement cost. Capital cost allowance was calculated for determining income tax payments and a marginal tax rate of 20% was assumed.

- (vii) Sensitivity analysis was carried out with price, yield and discount rate variations for all economic analyses. Other specific sensitivity analyses were done where appropriate. For financial analysis, changes in discount rates, marginal tax rates and residual values were tested through sensitivity analysis.
- (viii) The majority of the 1982 cost of production data was based on CRD's that were indexed with 1982 values. The remaining data was collected through in-person interviews within the specified irrigation climatic zones. This data was collected jointly by Strong-Hall & Associates, Marv Anderson & Associates Limited, and Environmental Management Associates.
- (ix) The 1984 irrigated and dryland data was collected by the Production and Resource Economics Branch of Alberta Agriculture through a survey of 48 farms (24 irrigated and 24 dryland farms). The majority of this data was collected in the Lethbridge-Taber area, which incidentally makes up the greatest portion of zone A2. The cost data for the remaining zones (A1,B,C,D) was based on the distribution of costs which was found to occur in 1982.
- (x) This study examined on-farm costs only. Off-farm public infrastructure costs were not taken into account.

2.1 Economic Analysis

To determine the on-farm economic benefits and costs of irrigation intensification and expansion the following methods and assumptions were used:

- (i) The general methodology described and assumptions given in the Introduction apply, except where otherwise stated.
- (ii) The analysis focused on two basic scenarios: intensification/extension of existing irrigation districts and private irrigation developments; and expansion into "new" areas. Ten base cases were examined; these are given in Table 1.1.

TABLE 1.1
DEVELOPMENT ALTERNATIVES BY IRRIGATION CLIMATIC ZONE

Irrigation Climatic Zone	Corresponding Soil Zone	Development Alternative
A1	Brown	Int./Ext. and Expansion
A2	Brown/Dark Brown	Int./Ext. and Expansion
B	Dark Brown	Int./Ext. and Expansion
C	Dark Brown	Int., Ext. and Expansion
D	Dark Brown	Int./Ext. and Expansion

- (iii) On-farm adoption for the intensification/extension scenario was assumed to take place according to the schedule given in Table 1.2. On-farm adoption rates for the expansion scenario were assumed to occur one-half as fast as for the intensification/extension scenario (i.e. over a 20 year period). The costs for expansion were therefore spread over a longer period.

TABLE 1.2
ON-FARM ADOPTION SCHEDULE FOR INTENSIFICATION/EXTENSION

Year	% of Potential
1	--
2	--
3	30
4	40
5	50
6	60
7	70
8	80
9	90
10	100

- (iv) Increases in irrigated area were based on 50 percent wheel roll systems (4 laterals per quarter section, 12 hour sets) and 50 percent stationary center pivots ($\frac{1}{2}$ mile long, 70 p.s.i. at the pivot). Both systems were assumed to be powered by natural gas. Capital costs of these two sprinkler systems were \$309 per acre for wheel roll and \$512 per acre for center pivot.¹
- (v) All sprinklers, motors and pumps had a life expectancy of 15 years. The PVC pipe (for the center pivot system) had a life span of 50 years and an estimated capital cost amounting to about 13.5 percent of total center pivot capital cost.²
- (vi) Other on-farm capital costs included the cost of dugouts. These had an estimated life expectancy of 50 years and cost about \$5,000 each (\$31.25 per acre for all wheel roll systems; \$37.88 per acre for the pivot system).
- (vii) Annual operation and maintenance costs for 14.4" (36/6 cm.) of water applied were estimated as shown in Table 1.3. These costs were included in production costs and are not included in the irrigation investment cost stream.
- (viii) The crop mix used in the analysis is provided in Table 1.4.

-
1. Cost data for 1983 were provided courtesy of Len Ring, Alberta Agriculture, Lethbridge, Alberta. All items deflated using CPI (deflation factor = .945).
 2. Marv Anderson & Associates Limited., An Economic Study of Alternative Irrigation Systems, Albion Ridge Irrigation Block, prepared for Alberta Agriculture, Edmonton, 1981, p. 2.11.

TABLE 1.3
ANNUAL OPERATION AND MAINTENANCE COSTS¹

Cost Item	Wheel Roll (\$/ac)	Center Pivot
Labour	5.10	2.40
Maintenance & Repairs	4.90	8.40
Energy (natural gas)	13.15	15.00
Total	23.15	25.80

1. The basic data on which these estimates were based used 12" (30.5 cm.) of water applied. For the purpose of this study, operating and maintenance costs were assumed to be linear. Thus, the data were increased by a factor of 1.2 (i.e. 36.6/30.5 = 1.2).

TABLE 1.4
IRRIGATED CROP MIX DATA BY IRRIGATION CLIMATIC ZONE¹

Irrigation Climatic Zone	Crop Mix ²						
	Wheat	Alfalfa	Barley	Sugar Beets	Oilseeds	Pasture	Other
	----- (%) -----						
Zone A1	41	14	14	6	6	5	14
Zone A2	28	22	24	4	3	6	13
Zone B	21	28	26	3	2	6	14
Zone C	8	33	21	-	4	27	7

1. Source: Alberta Agriculture, Economic Services Division, Lethbridge.
2. Represents percentage of cropped area.

- (ix) Annual cost of production estimates for dryland farming and revenue estimates for dryland and irrigated farming by irrigation climatic zone were extracted from the SSRBPP study¹ with minor changes. Irrigated crop production costs were derived from the SSRB, Economic Component.
- (x) Annual incremental returns for converting dryland to irrigated crop production were calculated from the basic cost and revenue data. This is summarized in Table 1.5.
- (xi) No residual values were included in the base case

TABLE 1.5
ANNUAL NET RETURNS TO IRRIGATED CROP PRODUCTION
1982-1984

Irrigation Climatic Zone	Dryland Revenue	Dryland Costs	Irrigated Revenue	Irrigated Costs	Total Income Change
-----(\$/ac.)-----					
1982					
A1	34.22	16.59	455.23	153.47	284.23
A2	36.70	16.68	358.32	132.71	205.59
B	56.03	27.55	331.91	128.51	174.93
C	54.69	25.80	251.73	103.69	119.15
D	69.38	42.72	300.51	121.72	152.13
1984					
A1	39.93	50.49	411.98	258.08	143.34
A2	42.84	51.15	323.13	222.36	92.46
B	65.38	78.81	299.32	217.44	68.45
C	63.83	74.09	227.01	183.81	32.94
D	80.97	117.56	271.00	210.78	23.63

1. Strong-Hall & Associates, Marv Anderson & Associates Limited, and Environmental Management Associates, South Saskatchewan River Basin Planning Program Evaluation Methodologies and Data Base, Alberta Environment, Calgary, July 1983.
2. Alberta Agriculture, Irrigation Water Requirements in the South Saskatchewan River Basin: Economic Component, Edmonton, Feb. 1983.

(xi) Sensitivity analyses were performed on certain variables as follows:

- a) Discount rates 3% and 7%;
- b) System costs $\pm$ 20%;
- c) Crop benefits - 20%;
- d) Incremental costs $\pm$ 10%; and
- e) Inclusion of a residual land value.

2.2 Financial Analysis

To determine whether farmers have sufficient incentive and suitably timed cash flows to make the investment in irrigation, the following transfer payments were evaluated:

Inflows

- (i) A water development grant from the Prairie Farm Rehabilitation Association (P.F.R.A.) was taken into account. This grant reimburses farmers for 1/3 of the eligible costs of irrigation projects to a maximum of \$2,200 per project.
- (ii) The total area of 10,000 acres, which was considered as the improved area, was assumed to be owned by 10 producers. This permitted the evaluation of 10 projects and thus 10 times the maximum grant per project of 10,000 acres.
- (iii) Crop insurance and Western Grain Stabilization (WGS) benefits were determined as stated in the Introduction.
- (iv) It was assumed that for any capital investment, the level of equity was 0, that is, the investments required by these projects were financed totally by loans.
- (v) Salvage value was based on the undepreciated portion of the sprinklers and dugout at either replacement time or at the end of the project (year 30).

- (vi) The residual value attributed to the land was based on the increased market value of the land resulting from irrigation, adjusted for the salvage value of the irrigation equipment. Sensitivity was done with no residual value. Sensitivity was also done with a residual value and an irrigated land purchase cost equivalent to the residual value.¹

Outflows

- (vii) The interest rate used for loans was 13%, with a repayment period of 10 years.
- (viii) The initial capital cost for the water right was charged in the first year of the project.
- (ix) Assumptions related to operating capital, crop insurance and WGS payments and marginal tax rates were as stated in the Introduction.
- (x) Capital cost allowance for tax purposes was calculated using a declining balance,² at a rate of 10% for sprinkler systems and a rate of 5% for dugouts.

3. Results

3.1 Economic Analysis

Results indicated that all development alternatives considered would be viable from an on-farm perspective. A summary of the results is

-
- 1. While this increased land value results partly from off-farm investments, the benefit accrues to the farmer. It can be argued that this benefit would be captured with or without investment in irrigation equipment, and would be a cost to a new irrigation farmer.
 - 2. Revenue Canada, Farmer's Income Tax Guide, 1982.

provided in Table 1.6. The discounted investment cost for sprinklers and dugouts was \$476 per acre for intensification and \$367 for expansion (reflecting different adoption rates and amount of discounting). In irrigation climatic zones A1 and A2 AECF's were between \$87 and \$178 per acre and B/C ratios between 2.0 to 2.3. Results were lower in zones B, C and D, the AECF's being between \$41 and \$98 per acre and B/C ratios 1.6 to 1.9. Internal rate of return (IRR's) were over 50 percent in all cases.

Even when subjected to more adverse economic conditions than assumed for the base case, all development alternatives were shown to be economically feasible. B/C ratios remained above 1.8 for zone A1 and above 1.5 for zones A2 and B when a discount rate of 7% was used or when costs increased by 20% or benefits decreased by 20%. Effects were even smaller with a 10% increase in incremental production costs. Inclusion of a residual value for land increased the AECF's and B/C ratios substantially.

TABLE 1.6
ECONOMIC PERFORMANCE MEASURES FOR IRRIGATION¹ (1982)

	DIC ² -----	NPV (\$/acre)-----	AECF -----	B/C (ratio)
Intensification/Extension				
Zone A1	476	2,739	178	2.35
Zone A2	476	1,850	120	2.03
Zone B	476	1,503	98	1.93
Zone C	476	872	57	1.64
Zone D	476	1,245	81	1.91
Expansion				
Zone A1	367	1,998	130	2.33
Zone A2	367	1,344	87	2.01
Zone B	367	1,089	71	1.90
Zone C	367	625	41	1.62
Zone D	367	899	58	1.88

1. Based on a discount rate of 5% and on 10,000 acre blocks.
2. DIC (Discounted Investment Cost). Intensification costs spread over 10 years, expansion over 20 years. The former costs were therefore discounted to a lesser extent, hence their higher value.

The 1984 economic performance measures (Table 1.7) also showed that extension and expansion would be feasible in all zones. However, in each zone and in both development options, the economic performance measures decreased considerably from the 1982 measures. As in 1982, the 1984 results indicate that irrigation climatic zones A1 and A2 exhibited the greatest potential with AECF's ranging from \$47 to \$107 per acre and B/C ratios ranging from 1.46 to 1.47. Results were again lower in zones B and C with AECF's ranging from \$13 to \$53 per acre and B/C ratios ranging from 1.17 to 1.44. Zone D in the two alternatives had an AECF range of \$37-52 per acre and a B/C ratio range of 1.57-1.60.

In the event of more adverse economic conditions, 1984 B/C ratios remained above 1.14 for zone A1, A2, B and D, when a discount rate of 7% was used or when costs increased by 20% or decreased by 20%. Just as in 1982, the 1984 values were smaller yet with a 10% increase in incremental production costs. The inclusion of a residual value for land increased the AECF's and B/C ratios substantially.

This comparison of 1982 and 1984 effects showed that each irrigation climatic zone experienced similar trends in response to changes in the economic conditions. Irrigation intensification/extension and expansion remained feasible but the degree of feasibility decreased substantially over the two year period. Expansion in zone A2, for example, experienced a B/C ratio decrease from 2.33 to 1.63, an AECF decrease from \$130 to \$78 per acre and an NPV decrease from \$1,998 to \$1,198 per acre (all at a 5% discount rate) between 1982 and 1984.

TABLE 1.7
ECONOMIC PERFORMANCE MEASURES FOR IRRIGATION¹ (1984)

	DIC ² -----(\$/acre)-----	NPV -----(\$/acre)-----	AECF	B/C (Ratio)
Intensification Extension				
Zone A1	476	1,652	107	1.65
Zone A2	476	998	65	1.46
Zone B	476	814	53	1.44
Zone C	476	296	19	1.19
Zone D	476	802	52	1.60
Expansion				
Zone A1	367	1,198	78	1.63
Zone A2	367	717	47	1.47
Zone B	367	582	38	1.43
Zone C	367	201	13	1.17
Zone D	367	573	37	1.57

1. Based on a discount rate of 5% and on 10,000 acre blocks.
2. DIC (Discounted Investment Cost). Intensification investment costs spread over 10 years expansion over 20 years, the former costs were therefore discounted to a lesser extent, hence their higher value.

TABLE 1.8
FINANCIAL ANALYSIS: IRRIGATION INTENSIFICATION BY IRRIGATION CLIMATIC
ZONE 1 NO RESIDUAL VALUE

	1982	NPV \$/ac	1984
Zone A1			
Before Financing	2564.85		1462.05
After Financing	2344.36		1241.56
After Fin. & Tax (20%)	1871.57		989.33
Tax Rate (30%)	1635.17		863.21
Zone A2			
Before Financing	1723.47		842.76
After Financing	1502.99		622.28
After Fin. & Tax (20%)	1196.40		491.83
Tax Rate (30%)	1043.11		426.61
Zone B			
Before Financing	1431.02		714.22
After Financing	1210.54		493.73
After Fin. & Tax (20%)	964.75		391.30
Tax Rate (30%)	841.85		340.09
Zone C			
Before Financing	860.62		257.03
After Financing	640.14		36.55
After Fin. & Tax (20%)	508.89		26.02
Tax Rate (30%)	443.27		20.75
Zone D			
Before Financing	1251.16		755.31
After Financing	1030.67		534.83
After Fin. & Tax (20%)	821.32		424.64
Tax Rate (30%)	716.64		369.55

1. Discount rate of 5% and
project life 30 years

TABLE 1.9

FINANCIAL ANALYSIS: IRRIGATION INTENSIFICATION BY IRRIGATION CLIMATIC
ZONE 1 WITH RESIDUAL VALUE

	1982	NPV \$/ac	1984
Zone A1			
Before Financing	2694.17		1591.37
After Financing	2473.68		1370.88
After Fin. & Tax (20%)	1987.96		1105.72
Tax Rate (30%)	1745.10		973.13
Zone A2			
Before Financing	1800.06		919.35
After Financing	1579.58		698.86
After Fin. & Tax (20%)	1265.33		560.76
Tax Rate (30%)	1108.21		491.71
Zone B			
Before Financing	1444.35		727.55
After Financing	1223.87		507.07
After Fin. & Tax (20%)	976.75		403.31
Tax Rate (30%)	853.19		351.42
Zone C			
Before Financing	876.23		272.64
After Financing	655.75		52.15
After Fin. & Tax (20%)	522.94		40.06
Tax Rate (30%)	456.53		34.02
Zone D			
Before Financing	1266.77		770.92
After Financing	1046.28		550.44
After Fin. & Tax (20%)	835.37		438.69
Tax Rate (30%)	729.91		382.82

1. Discount rate of 5% and project life 30 years

TABLE 1.10

FINANCIAL ANALYSIS: IRRIGATION INTENSIFICATION BY IRRIGATION CLIMATIC
ZONE WITH LAND COST AND RESIDUAL VALUE

	1982	NPV \$/ac	1984
Zone A1			
Before Financing	2161.87		1059.06
After Financing	1941.38		838.58
After Fin. & Tax (20%)	1468.59		586.35
Tax Rate (30%)	1232.19		460.23
Zone A2			
Before Financing	1484.82		604.10
After Financing	1264.33		383.62
After Fin. & Tax (20%)	957.74		253.17
Tax Rate (30%)	804.45		187.95
Zone B			
Before Financing	1389.47		672.67
After Financing	1168.99		452.18
After Fin. & Tax (20%)	923.20		349.75
Tax Rate (30%)	800.31		298.54
Zone C			
Before Financing	811.98		208.39
After Financing	591.50		-12.09
After Fin. & Tax (20%)	460.25		-22.62
Tax Rate (30%)	394.63		-27.89
Zone D			
Before Financing	1202.52		706.68
After Financing	982.04		486.19
After Fin. Tax (20%)	772.68		376.01
Tax Rate (30%)	668.00		320.91

1. Discount rate of 5% and
project Life 30 years

TABLE 1.11

FINANCIAL ANALYSIS: IRRIGATION EXPANSION BY IRRIGATION CLIMATIC
ZONE 1 NO RESIDUAL VALUE

	1982	NPV \$/ac
Zone A1		
Before Financing	1893.61	1082.51
After Financing	1742.79	931.69
After Fin. & Tax (20%)	1392.87	743.99
Tax Rate (30%)	1217.91	650.14
Zone A2		
Before Financing	1272.06	624.30
After Financing	1121.23	473.48
After Fin. & Tax (20%)	893.55	375.35
Tax Rate (30%)	779.72	326.29
Zone B		
Before Financing	1060.01	532.81
After Financing	909.19	381.99
After Fin. & Tax (20%)	726.23	304.47
Tax Rate (30%)	634.75	265.71
Zone C		
Before Financing	641.10	197.16
After Financing	490.28	46.34
After Fin. & Tax (20%)	391.56	36.41
Tax Rate (30%)	342.20	31.45
Zone D		
Before Financing	928.34	563.65
After Financing	777.51	412.82
After Fin. & Tax (20%)	621.35	329.60
Tax Rate (30%)	543.27	287.98

1. Discount rate of 5% and
project life 30 years

TABLE 1.12
FINANCIAL ANALYSIS: IRRIGATION EXPANSION BY IRRIGATION CLIMATIC
ZONE WITH RESIDUAL VALUE

	1982	NPV \$/ac	1984
Zone A1			
Before Financing	2018.12		1207.02
After Financing	1867.30		1056.20
After Fin. & Tax (20%)	1504.92		856.05
Tax Rate (30%)	1323.74		755.97
Zone A2			
Before Financing	1343.85		696.07
After Financing	1193.00		545.25
After Fin. & Tax (20%)	958.15		439.95
Tax Rate (30%)	840.72		387.29
Zone B			
Before Financing	1068.53		541.33
After Financing	917.71		390.51
After Fin. & Tax (20%)	733.90		312.14
Tax Rate (30%)	641.99		272.95
Zone C			
Before Financing	651.89		207.96
After Financing	501.07		57.13
After Fin. & Tax (20%)	401.27		46.13
Tax Rate (30%)	351.38		40.62
Zone D			
Before Financing	939.13		574.44
After Financing	788.31		423.62
After Fin. & Tax (20%)	631.06		339.31
Tax Rate (30%)	552.44		297.16

1. Discount rate of 5% and
project life 30 years

TABLE 1.13

FINANCIAL ANALYSIS: IRRIGATION EXPANSION BY IRRIGATION CLIMATIC
ZONE WITH LAND COST AND RESIDUAL VALUE

	1982	NPV \$/ac	1984
Zone A1			
Before Financing	1505.63		694.54
After Financing	1354.81		543.71
After Fin. & Tax (20%)	1004.89		356.01
Tax Rate (30%)	829.93		262.16
Zone A2			
Before Financing	1048.40		400.65
After Financing	897.58		249.82
After Fin. & Tax (20%)	669.90		151.70
Tax Rate (30%)	556.06		102.63
Zone B			
Before Financing	1033.47		506.26
After Financing	882.64		355.44
After Fin. & Tax (20%)	699.68		277.92
Tax Rate (30%)	608.21		239.16
Zone C			
Before Financing	607.47		163.53
After Financing	456.64		12.71
After Fin. & Tax (20%)	357.93		2.78
Tax Rate (30%)	308.57		-2.19
Zone D			
Before Financing	894.70		530.01
After Financing	743.88		379.19
After Fin. & Tax (20%)	587.72		295.96
Tax Rate (30%)	509.63		254.35

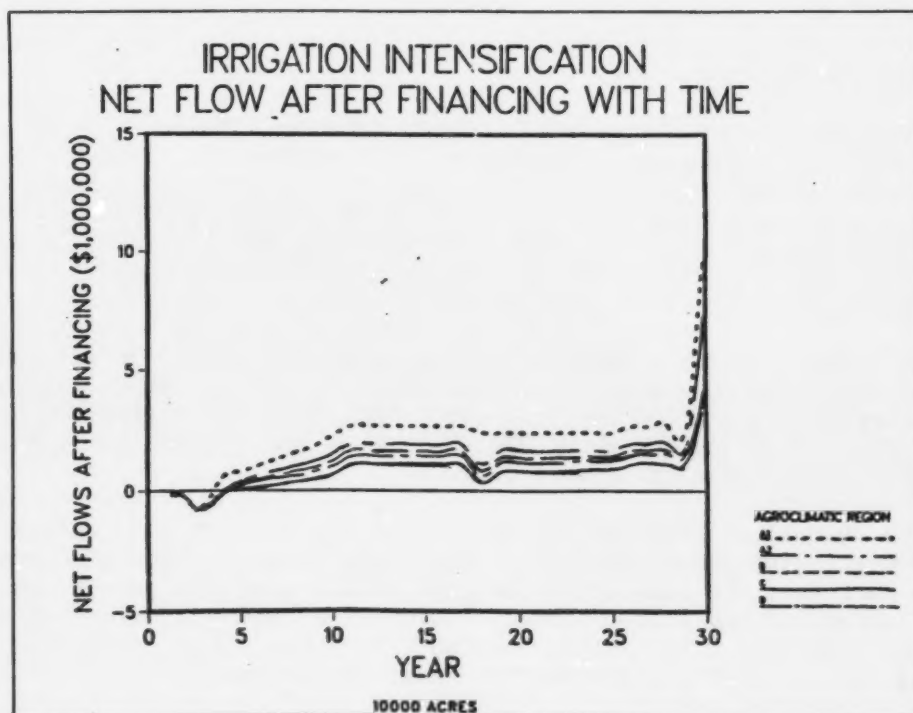
1. Discount rate of 5% and
project Life 30 years

3.2 Financial Analysis

Irrigation Intensification

Analysis was done at three levels: to all resources before financing; to the farmer's resources after financing; and to the farmer's resources after financing and taxes. Total undiscounted negative flows, in the order of \$12.50 to \$104 per acre (\$125,000 to \$1,045,000 per 1,000 acre unit), were experienced before financing during the first three years of the investment. After financing, these fell to between \$12.50 and \$41 per acre, in the first two years of the investment only. The stream of net cash flows after financing are provided in Figure 2. After taxes, the negative values were further reduced to between \$12.50 and \$33 per acre. Costs in the first year represented the charge for the water right. Those in year two represented incremental operating capital for year three.

FIGURE 2



Irrigation intensification would be financially feasible in all irrigation climatic zones examined, all zones having positive NPV's. Results presented in Table 1.8 indicate that irrigation climatic zone A1 had the highest values and zone C the lowest. The ranking of the zones was not affected by the level of analysis, whether done before or after financing or after taxes. In all zones, the returns to all resources (before financing) were about \$220 (or 9 to 33.5%) higher than those after financing and about \$354 to \$707 (36 to 67%) higher than those after financing and taxes, depending on the soil zone. All projects withstood the financing and tax assumptions used.

Removal of a residual value for land reduced the NPV by \$129 per acre (5%) in zone A1, but did not affect the feasibility of irrigation (Table 1.9). The addition of a cost for irrigated land (with a residual value included) had a greater impact. The NPV was reduced by \$532 per acre (20%) in zone A1 (Table 1.10). The impact was slightly smaller in zone A2 and substantially smaller in the other zones. This last observation reflects that the differences between irrigated and dryland values in zones B, C and D are less significant than those in zones A1 and A2.

From the sensitivity analysis it was found that irrigation expansion in zone A1 remained financially feasible up to a discount rate of 50% (before and after financing). This indicates that the IRR is greater than 50%. All cases were found to be feasible with a discount rate of 10% at each level of analysis. By increasing the tax rate from 20% to 30% (at a discount rate of 5%) all cases were still feasible, the NPV's after financing and taxes having only decreased by 14 to 16%, depending on the zone.

The 1984 financial analysis produced negative flows during the early years of development. These were in the order of \$12.50 to \$112 per acre (\$125,600 to \$1,118,000 per 1000 acre unit) before financing, during the first three years of the investment. After financing, these fell to between \$12.50 and \$53 per acre (in the first two years of the investment only). After taxes the negative flows were reduced to between \$12.50 and \$42 per acre.

In 1984, irrigation intensification remained feasible in all zones. Zone A1 again showed the most feasible results. In all zones, returns to resources before financing were about \$220 (16%-81%) higher than those after financing and about \$231-\$485 (44%-85%) higher than those after financing and taxes (Table 1.8).

The removal of residual values and the inclusion of a land cost had the same relative impact in 1984 as was found in 1982. This was caused by the fact that the same irrigated land values were used in 1984 as in 1982 (Tables 1.9 and 1.10). The inclusion of a land cost caused enough of a decrease in zone C to make the option infeasible. Also, at a discount rate of 10%, intensification was not feasible in zone C.

In 1982 and in 1984, zone A1 remained financially feasible up to a discount of 50% (before and after financing). The 1984 results also indicate that after financing and taxes (at a tax rate of 20%), intensification in zones B, C and D remained feasible at discount rates lower than 50%.

Irrigation Expansion

Negative flows during development were approximately half the value of those for intensification, reflecting the more gradual phasing in of the irrigation investment. However, all NPV's were below those of intensification. As was the case with irrigation intensification, zone A1 showed the best financial feasibility, zone C keeping the last position (see Table 1.11). Removal of a residual value did not affect feasibility but reduced all values (see Table 1.12). Inclusion of an irrigated land cost with a residual value had a similar impact to that in the intensification case (see Table 1.13). Changes in the discount rate produced the same impact as was shown for irrigation intensification. The sensitivity analysis showed that a change in tax rate produced a decrease in the AECF's of approximately 13% (at a discount rate of 5%), but all cases remained feasible.

Again in 1984 the negative net flows after financing were almost half the value of those for intensification. Zone A1 showed the best financial feasibility, zone C the least (see Table 1.11). The 1982 results also showed zone C to be the least financially feasible. The 1984 B/C ratios for expansion were either greater than or equal to the B/C ratios for intensification. The NPV's however, were greater in value in the intensification option than in the expansion option.

The removal of a residual value did not affect the feasibility of expansion but, as in 1982, it did reduce all values. The B/C ratios in each zone were greater in the expansion option than in the intensification option when the residual values were removed. With no residual value, the NPV's were greater in the intensification case for each zone (see Table 1.12). The inclusion of the irrigated land cost with the residual value produced similar results for expansion as for intensification (see Table 1.13).

Increasing the discount rate decreased the B/C ratio; this effect was similar to that of the intensification option. At a discount rate of 5% (the base case), a change in the tax rate from 20% to 30% resulted in an average decrease of 13.6%. Although the sensitivity analysis showed that an increase in the tax rate resulted in a decrease in the NPV, all zones remained feasible.

Irrigation expansion provided very similar results in 1982 and in 1984. In both years zone A1 was the most financially feasible zone in which to expand, zone C the least. In both years, removal of a residual value did not greatly affect feasibility. Inclusion of a land cost decreased B/C ratios and AECF's substantially in both years. Sensitivity analysis for both years yielded feasible results.

3.4 Conclusion

The findings suggest that irrigation intensification/extension in irrigation climatic zone A1 would give the highest return, with an AECF of \$178 per acre, followed by expansion in irrigation climatic zone A1 with an AECF of \$130 per acre. Returns reduced from zone A1, through A2 and B, with zone C having the lowest values. Irrigation climatic zone A1 is in the dry south-eastern portion of the province and consequently, the potential increase in yields from irrigation would be greater than for more moderate irrigation climatic zones. Despite the slower adoption rates assumed for the expansion scenario, the results were not much different from the intensification/extension scenario. This management alternative had a high investment cost of over \$300 per acre in present value terms. The comparison of zones by financial analysis was similar to that of the economic analysis. All financial values were lower than economic values, reflecting mainly the interest costs. Before financing NPV's fell slightly, in relation to the economic analysis, to \$2,694 per acre for intensification in irrigation climatic zone A1. After financing, these values fell further to \$2,473 per acre and still further, after taxes, to \$1,987 per acre. All projects remained financially feasible at each level of analysis. Removal of the residual value, or addition of a land purchase cost reduced all values but did not affect the feasibility of irrigation.

The nature of this analysis assumed that increased revenues from irrigation did not start to accrue until year three. However, there were costs related to water rights and incremental operating capital in years one and two respectively. These resulted in negative cash flows, both before and after financing, in the first two years of the project. These would have to be financed through savings, existing revenue from dryland farming, or through short term credit. Results for economic and financial analyses were quite similar, suggesting that transfer payments to and from the farmer (excluding infrastructure costs) are fairly well balanced. After financing, there were no negative flows from year three, indicating that increased revenues and financing conditions were sufficient to facilitate the investment in irrigation equipment.

The results from the 1984 analysis are very similar to those from the 1982 analysis. Irrigation climatic zone A1 gives the highest return in both years for both the intensification option and the expansion option. From 1982 to 1984 the intensification NPV in zone A1 decreased by \$11.03/ac. The expansion NPV decreased by \$8.11/ac. Regardless of these decreases, however, zone A1 remains the most feasible zone for both options in both years. In both years the returns per acre were highest for zone A1, then reduced through A2 and B, with zone C having the lowest values. In 1982 and 1984 all financial values were lower than economic values. In both years, all projects were financially feasible at all levels of analysis. Also, the projects remained feasible throughout the sensitivity analysis with the exception of the inclusion of a land cost for the intensification option in zone C (1984). At a 50% discount rate, intensification and expansion remains feasible in zone A1 in 1982.

In general terms, the two alternatives of irrigation intensification/extension and expansion, in the five irrigation climatic zones, were shown to be feasible in the two years studied. There was no major difference in feasibility between the two years. There was, however, decreases in the 1984 B/C ratios and AECF's. These decreases were brought about mainly by the increased costs of production in 1984. The 1984 analysis has shown that despite the large increase in irrigation production costs from 1982 to 1984, irrigation intensification and expansion are still feasible production alternatives in the agricultural industry in southern Alberta.

SESSION IV

Conference Summary and Recommendations

Chairman: S. L. Kramer

IRRIGATION ON THE PRAIRIES

-INDUSTRY WRAP-UP-

H. G. Koch

IRRIGATION ON THE PRAIRIES

-INDUSTRY WRAP-UP-

H. G. Koch

I want to thank the sponsors of the 4th Annual Western Provincial Conference for inviting me to participate in this wrap-up "rainguage" panel... "Rainguage" because our job is to measure the fallout benefits of the conference as they relate to industry, research and policy.

As you can see, my notes from the conference presentations are quite marked up, especially from today's where we have had presentations from the irrigation specialists versus those from the ag-economists. Differences of opinion do exist as you all have seen and heard.

I consider it a privilege to be able to share with you an "Industry Prespective" in response to the presentations that have been made by the speakers at this "Irrigation on the Prairies" Conference.

The irrigation industry contributes well over \$10.0 billion annually to the economies of Canada and the U.S. The irrigation industry is also a significant employer of professional, semi-skilled, and skilled laborers in both countries. This economic contribution does not take into consideration any crop production dollars or related dollars other than those directly attributable to the design, production, installation and test of ag related irrigation products and systems. Included in this estimate are the costs of labor and materials for all associated equipment such as pumps, motors, valves, etc., all of which are directly related to the final installed system. The landscape/turf segment of the industry represents approximately \$3.0 billion annually to the economy.

Before I begin my presentation, I have been asked by several of you to explain a little about The Irrigation Association, known as the IA. The IA was formed

in 1949 to represent the sprinkler manufacturers of the U.S. It has expanded over the past 35 years to become the trade association of the entire irrigation industry, representing all segments from the professors, engineers and consultants, to the manufacturers, distributors and contractors. We have approximately 1,000 members from the U.S., Canada and Mexico, plus members from 40 other countries. As you can see, the majority come from North America.

The IA provides service programs to its members in the form of:

- o Training to improve the operational use and maintenance of irrigation systems of all types.
- o An educational and examination program to certify irrigation systems designers for both turf/landscape and agricultural applications.
- o A standards and specification program for developing and approving industry standards nationally and internationally.
- o A recently established international consultant service for project identification and feasibility study.
- o Industry insurance programs for product liability, general liability and group medical insurance.
- o Management seminars for improved business performance.
- o Many other programs designed to assist you as a member of the IA. One such program could be the standardization of irrigation terms and symbols.

The overall goal of the IA is the advancement of the irrigation industry and its products and services for optimum user application and energy conservation.

You can help further this effort by working through and with the only trade association that represents this industry in both agricultural and landscape irrigation fields. We welcome Canadian membership in the IA as a strong contributor to our North American group.

Back to the conference. Over the past two days we have heard presentations on topics including:

- o General Irrigation in Western Canada
- o Water Suitability and Utilization
- o Soil Suitability and Utilization
- o Effluents for Irrigation and Fertilization
- o Computer Aids for Maximizing Economic Yields
- o Climatic Effects on Crop Production
- o Irrigation Efficiencies
- o Crop Optimization Through Managing the Limiting Factors
- o Water Resource Development Projects
- o Non-Intensive Irrigation
- o Supplemental Irrigation
- o Irrigation Project Approval--Major and Individual, and
- o Research in All of the Above Impact Areas

I believe "change" is the key to our industry's future. This change in practice and approach is underway and must continue in the future by focusing on better water management and use. Water loss through evaporation, seepage, runoff and wrongful application must be stopped.

Where does industry fit in all of this??? I submit it's right in the middle. Industry must convert research findings and user inputs into new technologies for irrigation hardware and systems. The challenge is to also provide new

technological advances that lend themselves to the retro-fit and/or modification of older systems such as low-pressure conversions, low-profiles, direct application systems, closed conveyances, etc. This must be done through the manufacturer's designs and processes that make the system and hardware fit the cost effective model of a free enterprise agricultural economy. I believe that agricultural production must and will become a true free enterprise economy in the not too distant future.

New technology must be directed at designing optimum irrigation systems to be offered to a very diverse and varied agricultural production economy. This also means that a fully integrated approach must be used for evaluating and developing new irrigated agricultural production projects including and starting with:

- o Sound conceptual ideas
- o Investigations and studies
- o Detail planning
- o Cost/benefit analysis
- o Review and selection of the best technology available
- o Detail design
- o Proper financing
- o Cost effective procurement
- o Proper installation
- o Checkout/startup/operation

I believe that industry will take its lead from experts like those of you here today. All of the scientific and technological elements discussed at this conference must continue to be addressed and, along with research, must move us into the future. The results of research and operational findings

must be properly submitted to industry for development of new hardware and systems technologies, and to the user/farmer for better management. Why?? Because irrigated agriculture as a segment of the total agriculture production scheme remains an economic business decision. This business decision must involve a cost-to-benefit analysis using the latest technology available, with an ever increasing awareness of the following:

- o Water resource conservation
- o Energy conservation
- o The need for increased yields
- o The use of improved management procedures for energy conservation and improved yields
- o Better understanding of compatability of crops-soils-water and the irrigation systems selected
- o Use of available wastewaters and effluents
- o Review and study of environmental impacts and possible contamination of soil and water sources, and
- o Review of all alternative economic uses affecting the project.

Underlying all of this is the legislative and regulatory process which can and will dictate certain factors and decisions.

The decision process is further complicated by the fact that the farmer/user is not always equipped to make the decisions necessary to assure success; therefore, he must rely on another element of the industry - the consultant to advise and assist him.

Irrigation, along with all of the other input elements we have discussed here today, is pushing the farmer/producer toward being a true professional manager and contributor to the world economy. To this end, he must continue

to produce food and fibers as economically and resourcefully as possible and with reasonable profits.

Adding to the increasingly complicated process of agricultural production is the increasing awareness of conservation regulations with regard to water resource use!!! As Dr. Veeman's video display showed, "Water is everything!" I believe it is very important in terms of irrigation and irrigation efficiencies to fully understand that "The true price paid for all water used can only be determined by its replacement cost."

Thank you.

RESEARCH NEEDS

J. D. Beaton
Potash & Phosphate Institute
Cochrane, Alberta T0L 0W0

Research needs identified by speakers at this conference and from other observations are summarized as follows:

I. THE SOIL AND WATER RESOURCE

A merging of water quality and soil compatability criteria would be helpful, especially for considering potential effects on soil salinity and permeability. Attention should be given to the three dimensional aspects of this unification. Research is needed on the use of a number of S containing materials for ameliorating poor quality waters with high SAR's or potentially high SAR's due to the presence of bicarbonate ions.

In the area of problem water utilization, systems of reclamation or management of saline soils should be developed where aquifer discharge is a factor in soil salinization. More work is needed on delineation of such aquifers and associated problem soil areas.

More definitive estimates of the relative influence of major soil properties on the suitability of soils for irrigation should be made.

For the application of soil information to design and management of irrigation projects, more baseline data is needed in the following areas: detailed soil surveys, extent and nature of wetlands and groundwater sources, land use management practices, and climatic measurements.

There should be more planning for future effluent irrigation projects because of anticipated increases in environmental pressures, as well as shortages of conventional supplies of irrigation water.

II. MAXIMIZING ECONOMIC CROP YIELDS

An interdisciplinary approach is essential in order to fit crop production factors together. Good research data on the relative contributions of various production inputs to maximize economic crop yields is needed in the development of computer assisted crop management models. How to deal with financial risk in high input situations must be adequately addressed.

Fourth Annual Western Provincial Conference Rationalization of Water and Soil Research and Management, "Irrigation on the Prairies", Saskatoon, Sask., November 25-27, 1985.

The potential restrictive influence of various aspects of climate on the benefits of irrigation needs to be evaluated. Although there is considerable information showing that irrigation greatly increases the need for and responses from N fertilizer, knowledge about changes in requirements for other plant nutrients is lacking. Applicability of the assumption made by Manitoba scientists that fertilizer N added to dryland soils is only 50 percent as effective as soil N should be verified for irrigated soil conditions.

Efficiencies of irrigation systems and the value of irrigation water need to be fully recognized.

The necessity of crop management systems that lower the unit cost of production or the MEY concept must be adequately demonstrated. It is essential to study the interactions that occur among the various inputs in such systems including rotation, species and variety selection, seed quality, seedbed preparation, planting date, seeding depth, seeding rate, plant population, row spacing, seeding equipment, and timeliness of operations such as tillage, seeding, pest control, and the application of plant growth regulators. In addition, research is needed on the significance of intensive crop management (ICM) practices such as the use of fungicides, insecticides, plant growth regulators, tramlines, etc.

In the case of high investment and high return commercial vegetable crops, research is needed on optimum soil fertility regimes for new cultivars and on the relationships between plant populations and soil fertility requirements. Problems of excessive use of N and P should be studied in terms of improved balance with other nutrients such as K, S, Zn, Cu, etc. which may become marginal under conditions of high N and P levels. The condition of P induced Zn deficiency may actually be due to plants with low or marginal Zn supplies losing their ability to regulate P uptake.

High research yields of canola are lacking and farmers often obtain much higher yields than agricultural scientists. Low research yields are of little value. Investigations are needed on the importance of management inputs that cost little or nothing extra. Differences among canola varieties in their response to fertilizer nutrients and to fertilizer placement need to be more clearly understood. The advantages of split applications of P versus deep banded only or residual fertilizer P should be assessed.

Research results at high yields of alfalfa are required. Low research yields are misleading. There is an urgent need to conduct alfalfa production research at high levels of management.

Proper harvesting programs are vital. It is also necessary to establish the impact of sound soil fertility practices on alfalfa yields and stand longevity. Use of plant analysis as a tool in monitoring stand performance needs to be developed further.

III DEVELOPING IRRIGATED AGRICULTURE

Information on how irrigation will improve the competitiveness of Prairie farmers on world markets and contribute to their overall economic well-being is required. The feasibility of non-intensive and supplemental irrigation in intensive crop management systems warrants additional study. Appraisal of major and individual irrigation projects must consider what farmers can achieve if the maximum economic yield concept is applied to irrigated agricultural production.

IV. NEEDS FOR INTENSIVELY MANAGED IRRIGATED CROPS

Water shortage is the primary factor limiting dryland crop production in the Prairies where amounts and frequency of precipitation are generally low and somewhat erratic. The severity of this restriction is readily apparent from previous research conducted at Outlook, Sask. where fertilized crops of soft wheat, barley, or rape yielded two to four times more under irrigation than they did under dryland conditions. On a cultivated acre basis, the yields from irrigated fields are about five times greater than from dryland fields which are usually fallowed every second or third year.

Most of these dramatic yield increases for irrigated crops were obtained with little change in management excepting substantial increases in rates of fertilizer N. Much research has been conducted on the combined effects of irrigation and fertilizer N on yield of the major grain crops. Little attention has been paid, however, to the potential gains to be derived from using intensive crop management (ICM) systems. Many of the ICM components should have a place when full or partial irrigation removes all or most of the constraints of insufficient soil moisture.

Both maximum economic yield (MEY) referred to earlier and ICM are crop production concepts or philosophies with the common goal of reducing unit production costs by optimizing production inputs. The end result will be to maximize crop yields and increase farm profits.

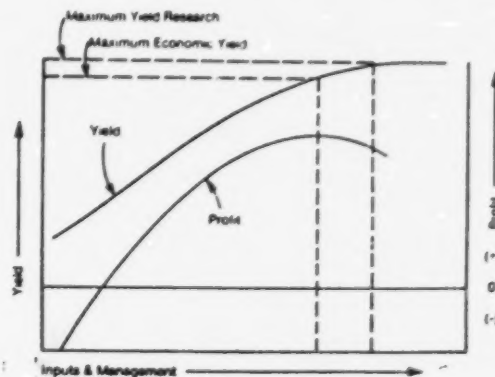
Maximum economic yield (MEY) is that crop yield where profits per acre are highest. It is simply that yield which gives the highest possible net return per acre or per hectare. It is a specific point on the yield curve-any high yield may or may not maximize returns. It happens that MEY is usually very close to maximum, within five or 10 percent, but never maximum. Maximum is for research. Economic maximum is for farmers.

High yield levels drop unit costs so farmers can produce a bushel or kilogram of wheat, canola, barley, flax, rye, alfalfa, corn or potatoes at least cost.

It should be noted that MEY does not mean low input cost per acre. In fact, it usually means higher per acre costs because high yields to the maximum economic level can require more inputs than most farmers now use.

Maximum economic yield is an upward moving target. It will shift from year to year depending on changes in input costs, prices received for commodities produced, and the adoption of new technology.

To produce at MEY Levels, farmers must be supplied with the best research information available. Maximum yield research (MYR) provides the agronomic basis on which MEY may be determined by applying economic analysis. No true MEY can be measured without the results of MYR. The relationship between maximum economic yield and maximum yield research is shown in the following figure.



Maximum economic crop yields are obtained only when topnotch management principles are accepted and adopted. These principles include commitment, planning and timeliness.

All of these principles are needed to achieve MEY production. Commitment... to a production system geared to utilize every input that contributes to profits. Planning..to organize the system on an orderly basis. Timeliness..to manage all production inputs to their maximum.

It takes time to co-ordinate existing technology into a MEY system. Consequently, MEY may not be reached for several years, but it is an opportunity for increasing profits. Also, it may take several years until cumulative management practices improve the farm or field enough to achieve MEY.

Many of the improved management practices in MEY add little to existing input costs. On the other hand, there are others which add significantly to total production costs per unit area. For example, greater use of fertilizer nutrients; increased use of crop protection chemicals; use of plant growth regulators to control lodging; more seed of higher quality for denser plant populations; new or modified seeding equipment for narrow row spacings and/or more uniform spacing; fertilizer deep banding equipment; and so forth, substantially increase input costs.

The key production inputs for intensive management MEY systems which should be considered and evaluated for irrigated crop production in the Prairies are briefly reviewed next.

1. High yielding crop species and varieties. Identify and use those crop species and varieties or hybrids that are most responsive to intensive management systems.

2. Seed quality. - Increased yields can come from high-quality, well-cleaned, and well-graded certified seed. Large seeds produce healthier, more vigorous plants than small kernels.

3. Seeding Rates - Seed size differs with variety. Thus, largerkerneled varieties need to be seeded at heavier rates in order to plant the same number of kernels per unit area as varieties having smaller kernels.

4. Plant population - More emphasis is being placed on establishing a certain number of crop plants per unit area. The density of plant populations should be increased to take advantage of intensive crop management practices and more favourable moisture conditions.

Relationships can be developed between 1000 kernel weight and the seeding rate in lbs/acre for different plant populations. Allowances for germination and purity are also necessary.

The establishment of populations close to 400 plants/m² was found to be a critical factor in reaching the outstanding yields of 172 bu/A of irrigated soft spring wheat at Bow Island, Alberta in 1985.

5. Row spacing - Ideally, each plant should have a symmetrical spacing for maximum yield. Although the equipment for such precision planting is not yet available, it is known that many crops including small grains and oilseeds sown at narrow row spacings generally produce higher seed yields than when sown in more widely spaced rows. European farmers routinely use four inch drills for seeding small grains. Dr. Tim Wright of the Agriculture Canada Research Station at Melfort, Sask. has obtained increases in wheat yields of 22 percent by narrowing row spacings from 9 to 4.5 inches. Researchers at the Beaverlodge

Research Station have reported similarly large yield increases of rapeseed by decreasing row spacings.

6. Row direction. Reports from widely scattered parts of the world indicate that planting in north-south rows is superior to east-west rows

7. Seedbed preparation - Establishment of a good stand is dependent on favourable seedbed conditions which should be firm and level to ensure a uniform seeding depth and close contact between seed and moist soil particles.

8. Maintain adequate nutrient and pH levels. - High crop yields demand high nutrient levels and favorable soil pH. The stimulatory effect of high rates of N in combination with irrigation on crop growth is well established. Less well known is how large responses to N increase the need for and benefits from other nutrients particularly P, K, S and perhaps B, Cu, Zn, Mn, etc.

Available P levels need to be raised to about 40 lbs/A (sodium bicarbonate extraction) for intensively managed crops and MEY. The value of supplemental Zn and Cu, and perhaps Mn should be established for soils high in available P status.

9. Rate and timing of N applications - Higher N rates and partitioning of N applications to fit the needs of the crop are two keys in successful intensive management of wheat. Total N needs will of course depend on location, yield goal, soil type, rotation, and crop species and varieties. For example, general guidelines for nitrogen fertilization of intensively managed winter wheat are shown below:

Time application	<u>Nitrogen application rate - kg/ha</u>	
	High soil N	Low soil N
At planting	22-34	28-34
Feekes stage 3	45-56	56-78
Feekes stage 8 to 9	<u>22-45</u>	<u>34-56</u>
Total	89-135	118-168

For irrigated spring wheat, two equal split applications, one before planting and one at the beginning of jointing (Feekes stage 5) may be adequate for maximum yields.

10. Disease control. - Conditions leading to high yields also provide a better environment for diseases. Mr. David Rourke has clearly shown the advantages of using foliar fungicides to control diseases in intensively managed winter wheat in Manitoba.

Applications of mancozeb increased yields by as much as 27 percent when tanspot and septoria glume blotch were the major diseases. This same chemical treatment increased grain yields by 63 percent where stem rust was controlled. Timing and rates of fungicide treatment are critical, as is good coverage of the target area. Root diseases may also depress crop yields if not identified and controlled.

11. Lodging control - The high fertilizer rates used in intensive crop management may increase the plant's susceptibility to lodging because of greater plant height and seed head size. Lodging should be controlled since it can result in poor yield response, losses in quality, and difficult and more costly harvesting. Growth regulators can be used to reduce plant height and lodging. Careful attention must be paid to the best time, rate and type of growth regulator.
12. Insect and weed control - Successful intensive crop management systems cannot tolerate either insect damage or weed competition. Most insect and weed problems can be controlled by the appropriate use of chemicals. Fields should be scouted frequently for early detection and timely control of potentially harmful pests.
13. Tramlines - Tramlines are a must in intensive crop production involving numerous trips across fields during the growing season. They help the speed, accuracy, and timeliness of all post-emergence applications. Tramlines are established by blocking or re-spacing drill discs to leave open spaces (tramlines) for wheel tracks. The wheel widths of the field equipment must match up with the tramline markers.
14. Rotations. - Growing crops in a rotation or in recurring succession on the same fields may be beneficial.
15. Timeliness of operations. - It is important to know what effect the timing of essential practices can have on yields in intensive crop management systems. Timing of tillage operations, seeding dates, irrigation, and pesticide and plant growth regulator application dates can all substantially influence the final outcome.
16. Water management - Moisture stress should be avoided, especially at critical stages in the development of the particular crop. On the other hand, over irrigation can be harmful. Irrigation scheduling will be of extreme importance in maximum yield systems which will likely benefit from close to optimum moisture conditions throughout the growing season. Irrigation should be continued until crops reach the appropriate stages of development e.g. hard dough stage of soft wheat.
17. Stubble management. - Since wind can account for much of the moisture lost from Prairie soils, intensive crop production

systems should use practical measures to reduce wind velocity and to protect crops from temporary periods of moisture stress, even when they are irrigated. Standing stubble can be effective in decreasing wind velocity at the soil surface and in keeping soil surface temperatures cooler. Over a four-year period of study at the Swift Current Research Station, cereal trap strips (2-ft. wide strips of tall stubble) left every 18 ft. of field width during swathing increased wheat yields an average 3 bu/ac/yr. The beneficial effect of these tall stubble strips is due partly to snow conservation and to windbreak effects at the beginning of the growing season.

Western Provincial Conference on
Soil and Water Research with focus on
"Irrigation on the Prairies"
November 25, 26 & 27, 1985, Saskatoon

IRRIGATION AND WATER POLICY IMPLEMENTATION

Professor J.A. Brown

My assignment is to reflect on the many excellent presentations and discussions we have heard at this conference, and to try to identify key elements of policy and program implementation strategy which need to be considered. In addition to the presentations made at this Conference, there have been several important studies completed recently which provide additional important insights which I shall also refer to. These studies include the 2 dozen or so 1985 research reports printed by the national Inquiry on Federal Water Policy; the 1985 UMA research report for the Saskatchewan Water Corporation regarding Saskatchewan Irrigation Project Appraisals; the study undertaken for the Alberta Irrigation projects Association in 1983-84 on the "Economic Impacts of Irrigation Development in Alberta Upon the Provincial and Canadian Economy," and the recent report of the Saskatchewan Task Force on Rural Development. Since I have been allotted only about half an hour to present this, I will have to be quite selective and brief.

This conference, as well as the research reports referred to, clearly demonstrate that when we tackle a theme like "Irrigation on the Prairies", we can't help but get drawn into a much larger arena of considerations. This is true whether we are examining potential benefits, potential capital investments and costs anticipated, or the many inter-relationships of water to land, forests, urban centres, regional development, or the multitude of users and potential users. In addition, there are such considerations as the needs of our neighbors and future generations. Such a wide range of considerations suggests several key elements of policy development and implementations:

[52,122]51

1. Because of the complexity and wide-ranging effects of proposed irrigation and water management projects, we have had great difficulty in adequately assessing the economic and social soundness of such projects, and consequently have had difficulty in apportioning benefits and costs. Tremendous progress has been made in the last 2 1/2 decades or so in evaluating projects, and now with computer technology and employing such approaches as simulation and input-output models, much more sophisticated and comprehensive results can be obtained.

Some will remember the evaluation period prior to the decision to build the Gardiner Dam. Analysts had a terrible time supporting a positive decision, because Benefit/Cost ratios which placed a very high weighting on agricultural net benefits were consistently low—considerably less than 1. When the decision was made by political leaders to proceed, it was concluded by some that the "P factor"—the political considerations—outweighed the economic analysis results. It appears that the political judgments involved may have been more comprehensive—and accurate—than those of the quantitative analysts.

The recent UMA evaluation of major irrigation proposals in Saskatchewan exemplifies the progress made in such evaluations. This has been made possible especially because of modern computer technology. However, there are still benefits which are not fully taken into account. For example, in irrigation development, what is the value of:

- enhanced community water supplies,
- recreation development and facilities,
- water supplies for industrial development,
- lower risk of drought-induced losses of commercial and service industries,
- more attractive and pleasing landscapes with productive gardens, trees, and parks, and
- better facilities for such things as education and medical care (the development of Lethbridge was cited as an example yesterday).

There is a major challenge in how to refine and improve our evaluation techniques and procedures.

2. Another critical reason why project evaluations need to be as comprehensive and defensible as possible is that there are tremendous competing pressures for the use of our available capital and revenues. It is clear in the literature, as it was in our Task Force enquiry that there is a wide range of views on the desirability of developing more major water-use projects. The media reports on the major recent undertakings in Alberta suggest a similar lack of complete consensus.

The UMA results regarding the possibility of developing several major projects in Saskatchewan are surprisingly favorable, and the study undertaken for the Alberta Irrigation Projects Association also shows strong positive results. In light of such results, it appears that, as a minimum, further consideration of development should continue.

3. The need for strong leadership at the senior government levels—both Federal and provincial—is obvious for things like adequate legislation, representation of society's goals and interests, taxation, planning and organization of projects, public education, and research. A key role of such leadership is to facilitate the development of all the benefits a project can reasonably provide without incurring costs or conflicts society does not want.
4. Combined with strong senior government leadership is the need for aggressive local government and private sector participation and direct involvement. This requires a fairly strong senior government presence, in the form of people, programs, and funds, at the local or regional levels. This is not to suggest that senior government involvement should overshadow local leadership and initiatives. Rather, it is to suggest the need for an overall environment of feasibility and encouragement within which local activity and development can flourish. Our history provides many

examples which illustrate the results of too limited local participation and support, or inappropriate direction from senior governments. A distinct danger of too strong senior government leadership or direction is that developments undesirable in the longer run may be imposed on a local area—with the possible support of financial incentives.

5. It is clear that most major water development projects will require the close cooperation of the federal and provincial governments. This is in recognition of the constitutional framework of Canada and the provinces, as well as the widespread effects of such projects. The Inquiry on Federal Water Policy clearly demonstrated that this is a basic element in the development of our water resources.
6. In planning, evaluating, and developing major water projects, it appears that much more consideration should be given to the potential multi-use or multi-purpose aspects of such project proposals. One important reason is to provide a broader base for recovery of the large capital investments required, and to pay future operating and maintenance costs. The widespread distribution of the benefits of the irrigation activities in Alberta is indicated in the 1984 study undertaken for the Alberta Irrigation Projects Association. This study indicated the positive effects on water users and other sectors of the economy, and concluded that... "The distribution of expected annual benefits arising from the current investments in regard to reclaimed land, increased irrigation acres and construction activities, etc., is 15 percent for water users, 56 percent for the province, and 19 percent for other Canadian provinces." The "66%" is especially significant because it reflects the high level of benefits of many people and economic sectors beyond the farm gate. The Saskatchewan Task Force on Rural Development reached a similar conclusion regarding the key role of water in the development of farms; small urban centres; and rural industry, recreation and tourism. A similar key role for water use was identified in the Federal inquiry on

water policy. This aspect of water development should be a basic concern of agencies such as the Saskatchewan Water Corporation and the Prairie Farm Rehabilitation Administration.

Research and Basic Data

Although considerable progress has been made in recent years, research on both the physical and economic aspects of irrigation has been less adequate than for dryland agriculture. Possibly this reflects the fact that in Western Canada agriculture is predominantly dryland-based. The irrigation croos acreage is only about 2 percent of the total cultivated acreage in the prairies. However, much more research is required on croos and crop varieties suited to soecific irrigation areas. This needs to be accompanied by economic research on economic feasibility and marketing opportunities.

The Saskatchewan Task Force on Rural Development concluded last May that consideration should be given to the establishment of at least one irrigation research and development centre for some urgently required applied and basic research. There is little doubt that in this province a major deterrent to the development of irrigation for the production of cereal, forage, soecialty and horticultural crops is the lack of adequate research. The capital investments and operating costs required by producers are too high for on-farm trial and error experimentation. And yet, to quite an extent this has been our approach.

Regarding data, it is a bit distressing that for some basic economic evaluations it is still necessary to use hypothetical farms for base budget information. Data collection and analysis have not been high priorities, and yet they are basic to planning, evaluation and monitoring. It was indicated at this conference that data on physical asoects related to engineering, and land and water relationships are also not fully adequate.

A research paper undertaken for the Inquiry on Federal Water Policy (Paper #16), cosponsored by the Science Council of Canada,

presents a fairly strong case for an expanded research program in Canada to base a sound water development and management program on in the future. Their arguments centre on the protection of a rich, precious resource; the effective use, development and management of our water resources; the use of water in economic development; and the conservation of water and related resources. The Inquiry identified a broad array of many research needs, including the following:

- efficiency of water use, especially regarding domestic, industrial, and agricultural uses,
- water quality, in terms of development and protection,
- more social science as well as interdisciplinary research,
- water as a constraint on regional or local development in both urban-centered and rural areas, and research on
- strategies which combine both supply and demand management methods.

The Report referred to many other research needs which would assist in decision-making regarding the protection, use, and further development of our water resources. This is an area which the government of Canada and the provinces have major responsibility for, especially regarding research funding and undertaking much of the research required.

Educational Activities

There are several important reasons why educational and extension activities should be given adequate attention in any program of irrigation or water development and management. To quite an extent this is a prerequisite for the success of any project or development as complex and costly as water projects generally are. To the extent possible farm owners, business operators in local communities, and the public in general should be familiar with the provisions, operations, objectives, and results of a major development program.

One of the main reasons why many people appear to have a negative image of irrigation is that the headlines tend to stress the massive public investments or expenditures in such programs, as well as the difficulties encountered in developing projects. Therefore, it is important for as many people as possible to have a full understanding

[52,122] 51

of both the expenditures and costs, as well as the benefits which will be gained by both the public and private sectors.

An adequate education program could serve to create interest in development opportunities, which in turn would foster investments and related economic activities. As a minimum, it would facilitate fuller public understanding of the issues and opportunities involved, and hence greater support—or opposition—as justified by the facts. This is going to be especially important if we are going to ask the public to become more involved—primarily through taxes—in programs of improving water quality and water conservation programs.

The importance of advisory services for individuals undertaking irrigation or water development projects appears to be widely recognized, and considerable resources are typically devoted to extension. And yet, it seems to take a long time for new irrigation operators to learn how to use irrigation or an assured supply of water effectively and to best economic advantage. It is a complex undertaking.

Economic evaluations of water development projects are very sensitive to the rate of uptake—the rate at which land and irrigation enterprises are developed. The rate at which development occurs and the benefits commence have a major impact on the rate at which the recovery of the large initial capital costs can begin. Various studies indicate that for planning purposes an uptake rate of 15 years is optimistic. If a project is assumed to have a life of 50 years or so, 15 years is a major portion of the total life span. A good extension program should help increase the uptake rate.

One limiting aspect of our extension efforts has been the shortage of answers and suitable technology. There are many unanswered questions of agronomy, varieties, chemicals, herbicides, crop alternatives and so on which are still hampering the rate of uptake. In the Outlook area, for example, a substantial irrigated acreage is still seeded to Neepawa—a wheat variety especially well

[52,122]51

suited to cope with conditions of drought and limited moisture. It isn't surprising therefore that some of the spring wheat yields are disappointing. A more supportive research program would result in a stronger extension program.

The Inquiry on Federal Water Policy concluded that steps should be taken to stimulate public awareness of water resources and to develop means for public participation in water policy decisions. The final report recommended provisions for public hearings on all major projects, as well as a vigorous program of public information on water management problems. Clearly, educational activities and extension should be a very important part of irrigation and water management development.

Conclusion

The challenges of sound irrigation and water policy and program development, and implementation, are exciting and full of opportunities. Hopefully, the many people involved will have the wisdom, creativity, courage, and determination to utilize our precious water resources more effectively.



"IRRIGATION ON THE PRAIRIES"

REGISTRATION

ADAM, Reg

Director, Alberta Affairs
P.F.R.A.
4th Floor, Cornerpoint Building
Edmonton, Alberta
T5J 1E2

ACTON, Don

Saskatchewan Institute of Pedology
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

AHRENS, Colin

Box 543
Rosetown, Saskatchewan
S0L 2V0

AILSBY, Howard

Minister's Advisory Council
Box 7
R.R. #1
Wymark, Saskatchewan
S0N 2Y0

ANDERSON, Darwin

Soil Scientist
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

ANDRESEN, Bill

Farmstead Dev. Technician
Saskatchewan Agriculture
Extension Branch- Ag. Engineering Sec.
3130 8th St. East
Saskatoon, Saskatchewan
S7K 2H6

BAILEY, Dr. L.D.

Head, Soil-Plant Science Section
Agriculture Canada
Box 610
BRANDON, Manitoba
R7A 5Z7

BARTON, Dave

River Basin Planner
Alberta Environment
83 Groveland Road
Sherwood Park, Alberta
T8A 3G7

BEATON, Dr. J.D.

Director,
Potash and Phosphate Institute of
Canada
Box 970
Cochrane, Alberta
T0L 0W0

BEATTIE, John

Area Manager
P.F.R.A.
Watrous, Saskatchewan
S0K 4T0

BEAUBIER, Gerry, Area Manager

P.F.R.A.
Box 1088
Swift Current, Saskatchewan
S9H 3X3

BELER, Randy

District Farmstead Technician
Dept. of Agric. Extension
350 Cheadle St. W.
Swift Current, Saskatchewan
S9H 4G3

BENNETT, Rod

Head, Research Section
Land Classification Branch
Alberta Agriculture
Agricultural Centre
Lethbridge, Alberta,
T1J 4C7

BERG, Eldor

Cominco Ltd.
124 Parkridge Place
Calgary, Alberta
T1J 4V9

BERGMAN, Vic

Box 142
Elbow, Saskatchewan
S0H 1J0

BERGSTEINSSON, John L.

Director, Special Projects
Saskatchewan Research Council
30 Campus Drive
Saskatoon, Saskatchewan
S7N 0X1

"IRRIGATION ON THE PRAIRIES"

BJONBACK, Derek

Head, Planning Div.
Inland Waters, Environment Canada
1901 Victoria Avenue
Regina, Saskatchewan
S4P 3R4

BOEHM, Marie

Saskatchewan Institute of Pedology
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

BOHRSON, L. T.

Senior Agrologist
Saskatchewan Agriculture
Bag 1000
Outlook, Saskatchewan
SOL 2N0

BOWER, Rod

Director, Water Resources
UMA Engineering Ltd.
514 Victoria Avenue
Regina, Saskatchewan
S4N 0N7

BRISTOL, O.P.

Agrologist
3610 Queen Street
Regina, Saskatchewan
S4S 2G3

BROWN, Dr. B.D.

Extension Agronomist
SW Idaho Research Station
Parma, Idaho 83660

BROWN, Dr. J.A.

Professor
Agricultural Economics Dept.
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

BUKOWSKI, Ted

Farmstead Dev. Technician
Saskatchewan Agriculture
Weyburn, Saskatchewan
S4H 2Z9

BUSSE, Derald

Southwest Advisory Board Member
Saskatchewan Water Corporation
Box 12
Site 10
Swift Current, Saskatchewan
S9H 3X7

CALPAS, J.G.

Director, Irrigation & Conservation Div.
Alberta Agriculture
Agricultural Centre
Lethbridge, Alberta
T1J 4C7

CAMERON, Dr. D.R.

Consultant
Normac A.E.S. Ltd.
Box 880
Swift Current, Saskatchewan
S9H 3W8

CAMPBELL, Donald J.

Director, St. Mary Irrigation District
Box 69
Burnett, Alberta
TOK 0J0

CARLSON, Keith

Minister's Advisory Council
Box 546
Outlook, Saskatchewan
SOL 2N0

CARNDUFF, Rick D.

Regional Manager
Southwest Region
Saskatchewan Water Corporation
350 Cheadle St. W.
Swift Current, Saskatchewan
S9H 4G3

CHANDNA, Paul

Alberta Agriculture
Project Planning Branch
Agricultural Centre
Lethbridge, Alberta
T1J 4C7

CHINN, Wally R.

Irrigation Specialist
Alberta Agriculture
Irrigation Branch
Box 640
Taber, Alberta
TOK 2G0

CHOMISTEK, Joe

Box 54
Ranier, Alberta
TOJ 2M0

"IRRIGATION ON THE PRAIRIES"

COLGAN, Brian

Director, Resource Planning Division
Alberta Agriculture
2nd Floor, 7000-113 St.
Edmonton, Alberta
T6H 5T6

COOK, Hugh

Pastures Manager
P.F.R.A.
Motherwell Building
1901 Victoria Avenue
Regina, Saskatchewan
S4P 0R5

COWAN, Dr. Wayne

Agric. Ext. Biologist
Ducks Unlimited Canada
1190 Waverley Street
Winnipeg, Manitoba
R3T 2E2

CRAM, Mart

Engineering Services Supervisor
Saskatchewan Water Corporation
West Central Region
Box 1398
Outlook, Saskatchewan
S0L 2N0

CROWLE, Leigh

Research Scientist
C.D.A.
Research Station
107 Science Crescent
Saskatoon, Saskatchewan
S7N 0X2

CUNNINGHAM, Jim

President
Precon Manufacturing Ltd.
3603 8th Avenue North
Lethbridge, Alberta
T1H 5C3

DILL, Don

Engineering Services Supervisor
Saskatchewan Water Corporation
Northwest Region
105 Provincial Bldg.
North Battleford, Saskatchewan
S9A 1E9

DANYLUK, J. F.

Vice-President
Saskatchewan Water Corporation
111 Fairford Street East
Moose Jaw, Saskatchewan
S6H 7X5

DAVIES, K.F.

Special Projects Eng.
P.F.R.A.
832-220 4th Avenue S.E.
Calgary, Alberta
T2G 4X9

DESJARDINS, Ronald

Resource Economist
Alberta Agriculture
Production & Res. Econ.
7000-113 Street
Edmonton, Alberta
T6C 1K4

DUBE, Pierce

University of Laval
Ste Foy, Quebec
G1K 7P4

DYBVIG, Wayne

Manager, Basin Planning
Saskatchewan Water Corporation
111 Fairford Street East
Moose Jaw, Saskatchewan
S6H 7X5

ECTOR, Doug

Advisory Board Member for the
West Central Region
Saskatchewan Water Corporation
Box 116
Elbow, Saskatchewan
S0H 1J0

EILERS, R.G.

Canada-Man. Soil Survey
University of Manitoba
Winnipeg, Manitoba
R3T 2N2

EILERS, Warren

Saskatchewan Institute of Pedology
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

"IRRIGATION ON THE PRAIRIES"

ENGEL, Albert
Head, Irr. Section, Design Div.
P.F.R.A.
15 Glasgow Street
Regina, Saskatchewan
S4X 1C9

ENNS, Samuel
Silver Acres Dairy
Dalmeny, Saskatchewan
S0K 1E0

ENTZ, Martin
Crop Science Department
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

EPP, Henry
Resources Management, Consultant
Sask Environment
3085 Albert Street
Regina, Saskatchewan
S4S 0B1

ERICKSON, L. G.
District Supervisor
Saskatchewan Water Corporation
West Central Region
Box 1398
Outlook, Saskatchewan
S0L 2N0

EWING, John
M.M. Dillon Ltd.
199 N. Leonard Street
Regina, Saskatchewan
S4N 5X5

FARRER, Donn
Farmstead Engineer
Saskatchewan Agriculture
#203, 640 Roberts Street
Swift Current, Saskatchewan
S4H 4R9

FJELD, H. A.
Irrigation Branch Division
Saskatchewan Agriculture
Bag 1000
Outlook, Saskatchewan
S0L 2N0

FLATEN, Don
Soils Specialist
Saskatchewan Agriculture
133-3085 Albert Street
Regina, Saskatchewan
S4S 0B1

GARNER, Lyman
Alberta Irrigation Council Member
Alberta Agriculture
Irrigation Secretariat
Room 265, Provincial Building
200-5th Avenue South
Lethbridge, Alberta
T1J 4C7

GEHL, Peter
District Supervisor
Saskatchewan Water Corporation
Northeast Region
Box 490
Nipawin, Saskatchewan
S0E 1E0

GIFFORD, Allan
Kintyre Farms Ltd.
Box 106
Glenside, Saskatchewan
S0H 1T0

GILLIES, Jon A.
Dept. of Agr. Engineer
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

GILLIS, A. Grant
Engineering Services Supervisor
Saskatchewan Water Corporation
Southwest Region
350 Cheadle St. W.
Swift Current, Saskatchewan
S9H 4G3

GORDON, Harry
President
Prairie Association for Water Management
(P.A.W.M.)
Box 1269
Hanna, Alberta
T0J 1P0

"IRRIGATION ON THE PRAIRIES"

GRACE, Dr. B.
Agrometeorologist
Agriculture Canada
Research Station
Lethbridge, Alberta
T1J 4B1

GRAYBIEL, Kim
Saskatchewan Executive Council
Box 101, Leg. Building
Regina, Saskatchewan
S4S 0E3
--- ---

GREGUS, Rudy
Director
Taber Irrigation District
Box 624
Taber, Alberta
TOK 2G0

GROSS, Gerry P.
Irrigation Agrologist
Saskatchewan Agriculture
Bag 1000
Outlook, Saskatchewan
SOL 2N0

GROVER, Claire T.
Director
P.A.W.M.
Box 1269
Hanna, Alberta
TOJ 1P0

GUILLAUME, Chuck
Assistant to the President
Saskatchewan Water Corporation
111 Fairford St. E.
Moose Jaw, Saskatchewan
S6H 7X5

HAGEN, Gordon W.
District Supervisor
Saskatchewan Water Corporation
Southwest Region
350 Cheadle Street
Swift Current, Saskatchewan
S9H 4G3

HALL, Ken,
Minister's Advisory Council
Box 67
Lucky Lake, Saskatchewan
SOL 1Z0

HAMLIN, T.W.
Irrigation Economist
Saskatchewan Agriculture
Bag 100
Outlook, Saskatchewan
SOL 2N0

HARAPIAK, J. T.
Chief Agronomist
Western Co-op Fertilizers Ltd.
Bag 2000
Calgary, Alberta
T2P 2N1

HARRON, Bill
Salinity Specialist
P.F.R.A.
2nd Floor, Motherwell Building
1901 Victoria Avenue
Regina, Saskatchewan
S4P 0R5

HARTMAN, G.P.
Irrigation Secretariat
Provincial Building
Lethbridge, Alberta
T1J 4C7

HECKER, Frank
Head, Soils Section
Alberta Agriculture
Land Classification Branch
Bag 3014, Agricultural Centre
Lethbridge, Alberta
T1J 4C7

HENRY, J. L.
Professor
Dept. of Soil Science
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

HEYWOOD, Richard, P. Ag.
Soil & Water Specialist
Conservation & Development Branch
Alberta Agriculture
Agricultural Centre
Lethbridge, Alberta
T1J 4C7

HINCHCLIFFE, Robert
2714 Klman Crescent
Regina, Saskatchewan
S4V 0M2

"IRRIGATION ON THE PRAIRIES"

HINZ, Denis

Advisory Board Member for
the Saskatchewan Water Corporation
Northwest Region
3077 6th Avenue W.
Prince Albert, Saskatchewan
S6V 5L7

HOLM, Jim

Ag. Rep., District #22
Saskatchewan Agriculture
3130-8th St. E.
Saskatoon, Saskatchewan
S7K 2H6

IRELAND, Bryan

Regional Manager
Saskatchewan Water Corporation
West Central Region
Box 1398
Outlook, Saskatchewan
SOL 2N0

IQBAL, Zafar

Planning Engineer
Alberta Agriculture
Agricultural Centre
Lethbridge, Alberta
T1J 4C7

JACKSON, Doug

Regional Engineer
Manitoba Dept. of Agriculture
25 Tupper St. North
Portage La Prairie, Manitoba
R1N 3K1

JAGOW, John

Box 455
Elbrose, Saskatchewan
SOL 0L0

JAME, Yih-Wu

Research Scientist- Irrigation
Agriculture Canada
Research Station
Box 1030
Swift Current, Saskatchewan
S9H 3X2

JAMES, David

Analyst
Office of Federal Economic Dev. Co-ordinator
3000-2221 Cornwall Street
Regina, Saskatchewan
S4P 2L1

JARVIS, Paul

Saskatchewan Water Corporation
111 Fairford Street East
Moose Jaw, Saskatchewan
S6H 7X5

JENKINS, G.C.

Chief
Department of Agriculture
915 Norquay Building
401 York Avenue
Winnipeg, Manitoba
T3C 0P8

JENSEN, Roy

Board Chairman
Lethbridge Northern Irrigation District
334-13th St. North
Lethbridge, Alberta
T1H 2R8

JOEL, Harvey

Box 291
Elbow, Saskatchewan
S0H 1J0

JONES, Murray

PFRA
Analytical Division
1901 Victoria Avenue
Regina, Saskatchewan
S4P 0R5

KING, W.J.

Irrigation Agrologist
Irrigation Branch, Saskatchewan
Agriculture
Bag 1000
Outlook, Saskatchewan
SOL 2N0

KINSEY, W. Roy

District Assessment Supervisor
Department of Municipal Affairs
Assessment Services
9925-107 St. NW
Edmonton, Alberta
T5K 2H9

KOCH, H.G.

Executive Vice President
Irrigation Association
Suite 1009, 1911 North Fort Myer Drive
Arlington, VA 22209

"IRRIGATION ON THE PRAIRIES"

KRAMER, S. L.

Assistant Deputy Minister
Saskatchewan Agriculture
3085 Albert Street
Regina, Saskatchewan
S4S 0B1

KRESCE, P.O.

Agronomist
Agribasics Co.
Box 112
Belgrade, Mont. 59714

KULSHRESHTHA, Suren N.

Prof. of Agr. Econ.
University of Saskatchewan
Kirk Hall 336
Saskatoon, Saskatchewan
S7N 0W0

LAFORGE, Art

Production Officer
Ag Canada
Box 8035
Regina, Saskatchewan
S4P 4C7

LANE, Steve

District Supervisor
Saskatchewan Water Corporation
Northeast Region
Box 490
Nipawin, Saskatchewan
S0E 1E0

LARSEN, Bill

Advisory Board Member for
Saskatchewan Water Corporation
Northwest Region
Box 157
Borden, Saskatchewan
S0K 0N0

LARSEN, R.L.W.

Editor
Irrigation Age Magazine
1999 Shepard Road
St. Paul, MN 55116

LARSON, P.H.

Area Manager
Alberta Field Operation
Ag Canada - PFRA
Soil & Water Cons. Service
Box 428
Hanna, Alberta
T0V 1P0

LAUDER, Ian

Advisory Board Member for
Saskatchewan Water Corporation
Northwest Region
Box 984
Shellbrook, Saskatchewan
S0J 2E0

LESKIW, L.A.

Consultant
Principal Pedology Consultants
9120-37th Avenue
Edmonton, Alberta
T6E 5L4

LESSAK, Ernie

Supervisor, Farmstead Development
Ext. Services - Saskatchewan Agriculture
Room 230, 3085 Albert St.
Regina, Saskatchewan
S4S 0B1

LINSLEY, J. L.

Irrigation Agrologist
Saskatchewan Agriculture
P.O. Bag 1000
Outlook, Saskatchewan
S0L 2N0

LIPISHAN, L.

Grad Student, University of Saskatchewan
3910 Taylor St. E.
Saskatoon, Saskatchewan
S7H 5J4

LOMAN, Ben

Board Chairman
Lethbridge Northern Irrigation District
334-13th St. N.
Lethbridge, Alberta
T1H 2R8

LUCIUK, Gerry

Manager, Program Planning
Ag. Canada, P.F.R.A.
2nd Floor, 1901 Victoria Avenue
Regina, Saskatchewan
S4P 0R5

LUST, Ivan

Sr. Engineer
Cochrane Lavalin
300-3303 Hillisdale Street
Regina, Saskatchewan
S4S 6W9

"IRRIGATION ON THE PRAIRIES"

MacDONALD, Kathleen
Alberta Agriculture
2nd Floor, 7000-113 St
Edmonton, Alberta
T6H 5T6

MAGNUSSON, Jan
Resource Economist
Saskatchewan Agriculture
Rm. 329-3085 Albert St.
Regina, Saskatchewan
S4S 0B1

MANDER, Jeff
Planning & Construction Co-ordinator
Saskatchewan Water Corporation
Box 1398
Outlook, Saskatchewan
S0L 2N0

MARANTZ, Dale
Soil Fertility Specialist
Alberta Agriculture
6909-116th Street
Edmonton, Alberta
T6H 2N2

MARKO, David H.
Manager of Marketing
ACRES International Ltd.
5th Floor, 10201 Southport Road S.W.
Calgary, Alberta
T2W 4X9

MARTENS, Harold
MLA
Minister's Advisory Council
Room 203
Legislative Building
Regina, Saskatchewan
S4S 0B3

MARTINSON, Russell
Instructor
Saskatchewan Technical Institute
Box 1420
Moose Jaw, Saskatchewan
S6H 4R4

MAYOH, Keith
Farmstead Dev. Tech.
Saskatchewan Agriculture
72 Smith St. E.
Yorkton, Saskatchewan
S3N 2Y4

McINTOSH, Tom
Economist
Saskatchewan Water Corporation
111 Fairford St. E.
Moose Jaw, Saskatchewan
S6H 7X5

McKENZIE, Dr. R.C.
Irrigated Soils and Crops
Alberta Agriculture
Brooks, Alberta
T0J 0J0

McKENZIE, Ross
Dept. of Soil Science
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

MENELEY, Bill
W.A. Meneley Consultants
1630 Argyle Street
Saskatoon, Saskatchewan
S7H 2W6

MIDDLETON, Betty
Graduate Student
Department of Agricultural Engineering
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

MILLER, Dale
Water Resources Engineer
MPE Engineering Ltd.
1222-3rd Avenue South
Lethbridge, Alberta
T1J 0J9

MONAGHAN, R.D.
Irrigation Specialist
Irrigation Branch
Alberta Agricultural Centre
Lethbridge, Alberta
T1J 4C7

MOORE, Carrie
Associated Engineering (Sask.) Ltd.
575 Park St.
Regina, Saskatchewan
S4N 5B2

MOROZ, Ed
Saskatchewan Area Manager
UMA Engineering Ltd.
3301-8th St. E.
Saskatoon, Saskatchewan
S7H 5K5

"IRRIGATION ON THE PRAIRIES"

MORTIN, Dave
Engineering Manager
Water Resources
UMA Engineering Ltd.
2540 Kensington Rd. N.W.
Calgary, Alberta
T2N 3S3

MOSER, Tony
Regional Manager
Saskatchewan Water Corporation
Southeast Region
110 Souris Avenue
Weyburn, Saskatchewan
S4H 2Z9

MUIRHEAD, Jack
Advisory Board Member for
Saskatchewan Water Corporation
Southeast Region
501-1st A Street
Estevan, Saskatchewan
S4A 0C4

NARGANG, Darryl
Branch Head
Saskatchewan Environment
3085 Albert St.
Regina, Saskatchewan
S4S 0B1

NICHOLAICHUK, Dr. W.
National Institute of Hydrology
Sedco Centre
Saskatoon, Saskatchewan
S7N 2X8

NORUM, Don
Professor
Dept. Agric. Engineering
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

O'GRADY, Kevin
612 Lansdowne Avenue
Saskatoon, Saskatchewan
S7N 1E3

OLFERT, Eric
Water Resources Instructor
Kelsey Institute
Idylwyld & 33rd Street
Saskatoon, Saskatchewan

OLSON, Tom
Regional Manager
Saskatchewan Water Corporation
Northwest Region
402 Royal Bank Tower
1101-101 St.
North Battleford, Saskatchewan
S9A 0Z5

OPDAHL, Irving
Box 282
Hanley, Saskatchewan
S0G 2E0

ORAM, Murray
Minister's Advisory Council
Box 219
Central Butte, Saskatchewan
S0H 0T0

PALMER, Dr. B.C.
Engineering Consultant
UMA Engineering Ltd.
Box 655
Lethbridge, Alberta
T1S 3Z4

PARKER, Robert
Eng. Services Supervisor
Saskatchewan Water Corporation
Southeast Region
110 Souris Avenue
Weyburn, Saskatchewan
S4H 2Z9

PARSONS, Elgin
Basin Engineer
Saskatchewan Water Corporation
111 Fairford St. E.
Moose Jaw, Saskatchewan
S6H 7X5

PAWLUS, Steve
Irrigation Technician
Saskatchewan Agriculture
Irrigation Branch
Bag 1000
Outlook, Saskatchewan
S0L 2N0

PEARSON, George
Agricultural Canada - P.F.R.A.
1901 Victoria Avenue
Regina, Saskatchewan
S4P 0R5

"IRRIGATION ON THE PRAIRIES"

PEDERSON, Clint

Agrologist
Bank of Nova Scotia
Regional Office
111-2nd Avenue South
Saskatoon, Saskatchewan
S7K 1K6

PEEKE, Des

Advisory Board Member for
Saskatchewan Water Corporation
East Central Region
Box 257
Semans, Saskatchewan
SOA 3S0

PEHL, Arnold

Agrologist
Sask. Agriculture
Irrigation Branch
Bag 1000
Outlook, Saskatchewan
SOL 2N0

PELTON, William

Agriculture Canada
Research Branch
1901 Victoria Avenue
Regina, Saskatchewan
S4P 0R5

PELTZER, Rudy

Director
Eastern Irrigation District
Box 8
Brooks, Alberta
TOJ 0J0

PENKAVA, Dr. F.F.

Agricultural Engineering Dept.
University of Manitoba
Winnipeg, Manitoba
R3T 2N2

PETERS, John R.

Director
School of Agriculture
University of Saskatchewan
Saskatoon, Saskatchewan
S7J 2R7

PIERCY, Jack

Chairman, Advisory Board Member for
Saskatchewan Water Corporation
West Central Region
Box 757
Rosetown, Saskatchewan
SOL 2V0

PRITCHARD, Dr. M.

Horticultural Section
Plant Science Department
University of Manitoba
Winnipeg, Manitoba
R3T 2N2

PROZNIAK, Jozef - Water Resources Engineer

MPE Engineering Ltd.
1222-3rd Ave. S.
Lethbridge, Alberta
T1J 0J9

PRUDEK, V.C.

Box 267
Bow Island, Alberta
TOK 0G0

QUINN, Dr. F.J.

Director of Research
Inland Water, Directorate
Environment Canada
Ottawa, Ontario
K1A 0E7

RADIGAN, Paul

Project Co-ordinator
Saskatchewan Water Corporation
111 Fairford St. E.
Moose Jaw, Saskatchewan
S6H 7X5

RAMSEY, Donald

Manager
The SNC Group
2222 Ave. C. North
Saskatoon, Saskatchewan
S7L 6C3

RANDALL, Wayne

Operation Manager
Saskatchewan Water Corporation
Box 310
Watrous, Saskatchewan
S0K 4T0

"IRRIGATION ON THE PRAIRIES"

RENNIE, Don
Dean of Agriculture
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

ROBERTS, Don J.
Project Manager
ACRES International Ltd.
5th Floor, 10201 Southport Rd. S.W.
Calgary, Alberta
T2W 4X9

ROLL, D.A.
Regional Irrigationist
Alberta Agriculture
Regional Agricultural Centre
Bag Service #1,
Airdrie, Alberta
TOM 0B0

SAMP, Manfred
Program Co-ordinator
PFRA- Manitoba Affairs
401-1 Wesley Avenue
Winnipeg, Manitoba
R3C 4C6

SCHMIDT, Garry
Minister's Advisory Council
Box 36
Russell, Saskatchewan
SOM 2S0

SCHREFFLER, Arnold
Advisory Board Member for
Saskatchewan Water Corporation
East Central Region
Box 143
Liberty, Saskatchewan
SOG 3A0

SCHUSTER, A.C.
Chief Engineer
Saskatchewan Water Corporation
111 Fairford St. E.
Moose Jaw, Saskatchewan
S6H 7X5

SEMESCHUK, Tom
Cabrian Engineering
119-105 St. E.
Saskatoon, Saskatchewan
S7N 1Z2

SEPHTON, George
Head Water Development Planning
P.F.R.A.

1901 Victoria Avenue
Regina, Saskatchewan
S4P 0R5

SHAYKEWICH, Dr. C.F.
Professor
Soil Science Department
University of Manitoba
Winnipeg, Manitoba
R3T 2N2

SINCLAIR, Morley
Engineering Assistant
Saskatchewan Agriculture
Irrigation Branch
Bag 1000
Outlook, Saskatchewan
SOL 2N0

SINCLAIR, Rob
Prog. Head, Water Resources
Kelsey Institute
Box 1520
Saskatoon, Saskatchewan

SLINKARD, Al
Senior Research Scientist
Crop Dev. Centre
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

SMITH, Russell L.
Watershed Research
N.H.R.I.-Environment Canada
Sedco Centre
15 Innovation Blvd.
Saskatoon, Saskatchewan
S7N 2X8

STEIERT, Tony - S.A.R.M. Rep.
Alsask, Saskatchewan
SOL 0A0

STEWART, John W.B.
Prof. & Head, Soil Science
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

"IRRIGATION ON THE PRAIRIES"

STEWART, Karen
Box 99
Outlook, Saskatchewan
SOL 2N0

STEWART, Keith
Box 99
Outlook, Saskatchewan
SOL 2N0

STUSHNOFF, Richard
Sask. Institute of Pedology
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

SUDOM, Dale
Director
Provincial Agriculture
Box 4750
St. Johns, NFLD
AOA 2E0

SUTHERLAND, Don
Box 176
Borden, Saskatchewan
SOK 0N0

SWEENEY, Michael
Assoc. Prof. - Soil Science
North Dakota State University
Waldron Hall 201
Box 5575
Fargo, ND 58105

TELFER, Gerry
Utility Manager
Saskatchewan Water Corporation
Box 310
Watrous, Saskatchewan
SOK 4T0

TEO, Ban-Kiat
University of Saskatchewan
Department of Biology
Saskatoon, Saskatchewan
S7N 0W0

TIMMERMAN, Robin
Sales Manager
Precon Manufacturing
3603-8th Avenue North
Lethbridge, Alberta
T1H 5C3

THIELE, Tim
Area Manager
Ducks Unlimited
Box 4465
Regina, Saskatchewan
S4P 3W7

THOMAS, Rob
Sales
ARMCO - Westeel Inc.
434 McDonald Street
P.O. Box 1010
Regina, Saskatchewan
S4P 3W7

THOYAMANI, K.P.
Graduate Student
University of Saskatchewan
#3,806 Bedford Road
Saskatoon, Saskatchewan
S7N 1N9

TOLLEFSON, Laurie
Farm Manager
P.F.R.A.
Outlook, Saskatchewan
SOL 2N0

TORRIE, Jim
Minister's Advisory Council
Box 91
Riverhurst, Saskatchewan
SOH 3P0

TRASK, Leonard
Advisory Board Member for
Saskatchewan Water Corporation
Northwest Region
Box 56
Paradise Hill, Saskatchewan
SOM 2G0

Van der GUGTEN, C.A.
Manager, Water Resource
The SNC Group
2222 Avenue C North
Saskatoon, Saskatchewan
S7L 6C3

Van DEURZEN, Tony
Alberta Agriculture
Alberta Agricultural Centre
Lethbridge, Alberta
T1J 4C7

"IRRIGATION ON THE PRAIRIES"

VEEMAN, Dr. T.S.

Professor
Rural Economy Department
University of Alberta
Edmonton, Alberta
T6G 2H1

VOPNI, Randy

Farmstead Eng. Specialist
Saskatchewan Agriculture
110 Souris Avenue
Weyburn, Saskatchewan
S4H 2Z9

WANKEL, Wesley J.

Planning Section Head
Alberta Agriculture
Agricultural Centre
Lethbridge, Alberta
T1J 4C7

WEITERMAN, Garth

Soils Agrologist
Saskatchewan Agriculture
Irrigation Branch
Bag 1000
Outlook, Saskatchewan
SOL 2N0

WETTERSTRAND, Gerry

Manager, Sask. Regional Division
Ag Canada, P.F.R.A.
Motherwell Building
1901 Victoria Avenue
Regina, Saskatchewan
S4P 0R5

WETTLAUER, Bob

Director, Policy & Analysis
Ag Canada, P.F.R.A.
Motherwell Building
1901 Victoria Avenue
Regina, Saskatchewan
S4P 0R5

WHEATLEY, J.R.

Manager, Technical Services
Saskatchewan Water Corporation
111 Fairford St. E.
Moose Jaw, Saskatchewan
S6H 7X5

WIEBE, Rob

District Supervisor
Saskatchewan Water Corporation
Box 1398
Outlook, Saskatchewan
SOL 2N0

WILLIAMSON, Reg

Irrigation Manager
P.F.R.A.
Box 1088
Swift Current, Saskatchewan
S9H 3X3

WOOD, George B.

President
Co-Res Systems Inc.
Box 367
Cambridge, Ontario
N1R 5V5

WYATT, Gary

Manager- Engineering Design
Sask. Parks & Renewable Resources
3211 Albert Street
Regina, Saskatchewan
S4S 5W6